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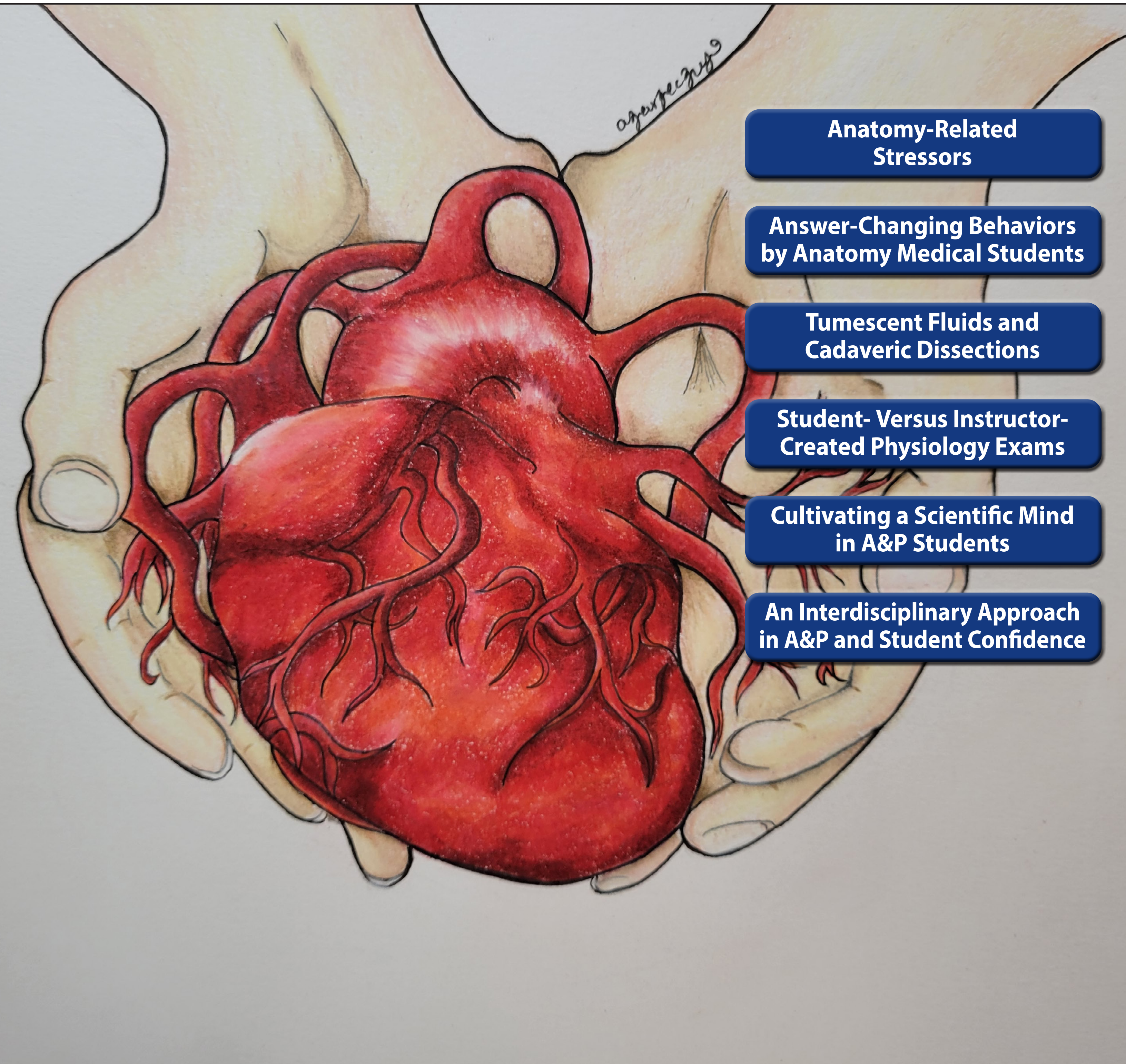

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Anatomy-Related Stressors for Allied Health Students

Oheneba Boadum, MBChB, MA, MS[1], Audra F. Schaefer, PhD[1], Ellen M. Robertson, PhD, OTR/L[2]

[1]Department of Advanced Biomedical Education, Division of Clinical Anatomy, University of Mississippi Medical Center, Jackson, MS, USA

[2]Department of Physician Assistant Studies, Randolph-Macon College, Ashland, VA, USA

Corresponding author: oboadum@umc.edu

Abstract

Most health-related educational programs are traditionally stressful. One of the most frequent academic stressors that students report is their gross anatomy experience. A variety of symptoms, including stress, anxiety, and emotional distress, have been reported among students in anatomy, particularly concerning working with anatomical donors. However, the literature remains sparse concerning what other stressors could contribute to the experiences of students in a donor-based anatomy course. Reports of stress are also common among students in non-donor dissection-based courses. This study aimed to investigate what stressors occupational and physical therapy students experienced in both the laboratory and lecture components of their anatomy course. A thematic analysis based on a descriptive phenomenological study was designed. This allowed the exploration of anatomy-related stress from the students' perspective as a phenomenon they experienced during their study. Thematic responses were categorized into laboratory and non-laboratory anatomy-specific stressors. Themes included dissection supervision, dissection group dynamics, emotional preparation, fear of death, condition of anatomical donor, anatomical donor's subcutaneous tissue, quality of dissection, previous anatomy experience, anatomical terminology, amount of information, teaching styles, fear of failure, self-directedness, and time constraint. Most stressors pointed to a course or curriculum issue and could be potentially modifiable. Knowledge of these stressors that students face could contribute to understanding the challenges in the study of anatomy from the student's perspective and contribute to future efforts in addressing these stressors. https://doi.org/10.21692/haps.2024.007

Key words: stressors, gross anatomy, cadaver, dissection, adipose tissue

Introduction

Anatomy Education in Allied Health

Many health science disciplines consider a comprehensive understanding of gross anatomy to be crucial to becoming a competent healthcare provider. Typically, gross anatomy courses have a didactic component paired with a laboratory-based component; the latter is taught by performing dissection or prosection, using plastinated specimens or computer-based approaches (Abdullah et al., 2021; Houser & Kondrashov, 2018). Because of the clinical significance and immediate translation of anatomical knowledge into clinical work, anatomy has become a foundational requirement for the successful practice of most health disciplines, including occupational therapy (OT) and physical therapy (PT) (Arráez-Aybar et al., 2010; Sbayeh et al., 2016). Anatomy is often one of the first courses allied health students take in their curriculum (Blum et al., 2020). In this first clinical discipline, students in anatomy may encounter anatomical donors as their first patients (McDaniel et al., 2021).

Donor-based anatomy dissection courses are one of the most recommended teaching methods for anatomy in an allied health curriculum because of opportunities to incorporate other learning opportunities such as surface palpation, ethical behaviors in handling the anatomical donors, team-based learning, and hands-on dissection (Champney, 2019; Ghosh, 2020; McDaniel et al., 2021; Palmer et al., 2021; Schofield, 2014). However, students across health-related schools have traditionally described the study of anatomy as stressful, with the predominantly reported stressor being donor-related anxiety experienced in dissection-based anatomy courses (Curfman et al., 2018; Romo-Barrientos et al., 2019, 2020; McDaniel et al., 2021; Thompson & Marshall, 2020). Researchers have also observed anatomy-related stress within veterinary-based and other non-donor-based anatomy courses (Terrado et al., 2023). The concept of anatomy-related stress in allied health settings appears multifaceted with several contributing factors.

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While quantitative studies reporting negative emotional states such as anxiety and stress among students studying anatomy are important, there is a need to explore what precipitates them. This will improve our understanding of the meaning of these anatomy-related stressors as a lived experience from the view of the students experiencing it. To better understand students' experience of stressors in anatomy, the phenomenon of stress can therefore be investigated as a universal essence among participants, and their descriptions interpreted as a life world experience.

The day-to-day work of most allied-health professions, including OT and PT, requires the application of anatomical knowledge to perform accurate evaluations and implement effective interventions (Blum et al., 2020; Schofield, 2018; Simmons et al., 2022). An inadequate understanding of anatomy could lead to ineffective or detrimental therapeutic interventions in both OT and PT professions (Giles et al., 2021; Yammine & Violato, 2014). Therefore, while allied health students may gain anatomical knowledge through anatomy education, how they translate and use this anatomical knowledge is important in clinical practice (McLachlan et al., 2004). Concerningly, most students who will rely on anatomy in their practice see their anatomy education as a stressful experience (Lester et al., 2010).

Anatomy-Related Stress

In this study, the working definition for anatomy-related stress includes laboratory dissection-related factors and non-laboratory related factors that students described as stressful to their gross anatomy learning experience. Studies regarding the phenomenon of stress and its impact on student health are not uncommon (El-Ghoroury et al., 2012; Hill et al., 2018). Particularly, working or studying in specialized environments such as a donor-based anatomy laboratory may come with its own unavoidable stressors, many of which are inseparable from the environment (Romo-Barrientos et al., 2020). Lester et al. (2010) reported identifying elevated levels of stress and inflammatory markers in OT students from the beginning of their gross anatomy course through to the end of the final course exams, and students being at risk of developing immune dysregulation even in the absence of perceived stress.

Finkelstein and Mathers (1990) reported that five percent of students taking gross anatomy experienced severe disturbances including nightmares, insomnia, intrusive emotional disturbances, depression, and impairment in learning. Additionally, a large fraction of students also experienced similar but less severe symptoms comparable to post-traumatic stress disorder. These stressors have been specifically highlighted in studies that looked at students within donor-based anatomy programs (Chang et al., 2018; Romo-Barrientos et al., 2019). Anxiety, high levels of emotions, apprehension, confusion, fear, and uncertainty are among other emotions recorded in the literature (Bati et al., 2013; Kotzé & Mole, 2013).

In the dissection laboratory, these emotional experiences are commonly related to death anxiety or fear of death (Allison et al., 2021; Grochowski et al., 2014). The exposure of students in a donor-based dissection course to death and dying brings students an additional stressor of confronting their own mortality and death (Aziz et al., 2002). Allison et al. (2021) described an increase in students' fear of dying after beginning a dissection-based anatomy course. Subsequently, several coping mechanisms have been observed in students following their encounter with the stressor of death-related anxiety (Fleischmann, 2003; Kotzé & Mole, 2013). Students have been shown to engage in behaviors such as avoidance of both human and animal remains within the anatomy laboratory and being overwhelmed by the emotions brought up by death while working with anatomical donors (Allison et al., 2021).

It is possible that students may hide their emotional struggles in a donor-based environment due to peer pressure or from fear of being seen as incompetent upcoming health professionals. In a study by Grochowski et al. (2014), students masked their emotional experiences to the stressor of working with anatomical donors. The observed student behaviors and confessions of emotional struggle during one-on-one interviews with the psychiatrist contradicted their Beck Anxiety Inventory results. Interviews showed that most students battled with symptoms of anxiety, including insomnia, intestinal upsets, increased arguments with significant others, fatigue, physical pain, and loss of appetite, which they did not disclose in the objective anxiety inventory. The risk of students concealing their emotional struggles in anatomy dissection should prompt faculty to seek ways to reduce potential stressors encountered by students within anatomy education.

The literature reports similar perceptions of stress by students studying anatomy regardless of the learning medium (e.g., animal dissection, prosection, or non-cadaveric technology) (Randler et al., 2016; Romo-Barrientos et al., 2019; Terrado et al., 2023). This reported uniformity of anatomy-related student stress (Bernhardt et al., 2012) suggests that other anatomy course-specific stressors should be investigated. Information regarding additional anatomy-specific stressors outside of using anatomical donors remains scarce, with an even greater lack of investigation specific to allied health students within OT and PT programs (Curfman et al., 2018; Romo-Barrientos et al., 2019).

With the literature focused mainly on death-related anxiety as a predominant stressor in the laboratory component of anatomy education (Allison et al., 2021) this study was conducted to investigate what other laboratory and non-laboratory anatomy-related stressors students faced during their gross anatomy course. Appreciating the presence of additional stressors could provide anatomy educators with more information regarding the source of stress within the study of anatomy. It will also allow course directors and faculty members to improve modifiable stressors and provide options

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to reduce students' perception of stress for non-modifiable stressors. A change in student perception could lead to an increased interest in learning anatomy and the formation of a stronger foundation of anatomical knowledge for future clinical skills development.

Materials and Methods

Context of the Gross Anatomy Course

The University of Mississippi Medical Center (UMMC) School of Health-Related Professions (SHRP) offers several baccalaureate, post-baccalaureate, master's, and doctoral degree programs. The Doctor of Occupational Therapy program admits 40 students each year for the three-year program, and the Doctor of Physical Therapy admits 50 students each year for the three-year degree. First-year students in both OT and PT begin their course of study in the summer by taking a gross anatomy course (didactic and laboratory with dissection) for ten weeks. These students, although taking anatomy together, have different program entry requirements, diverging courses of study in their programs, and attract people from different experiences and backgrounds.

The anatomy course is divided into three blocks: back and upper extremity; lower extremity and thorax; abdomen and neck. Within each block, students are assessed with weekly lecture and laboratory quizzes, along with multiple-choice questions and practical exams at the end of every block. Class meets daily throughout the 10 weeks with typical days consisting of one hour of lecture followed by a three-hour laboratory session comprised of surface anatomy, bone study, and dissection of anatomical donors under the guidance of faculty and graduate teaching assistants. OT and PT students, regardless of gender, age, or anatomical experience, are randomly placed together into dissection groups of four or five per anatomical donor for the gross anatomy laboratory dissection. All students are required to attend every laboratory session. Students receive a separate lecture and laboratory course grade and must earn an average of 75% in each gross anatomy course section to pass. Due to the nature of the program's expectations, if a student fails either the lecture or laboratory course, they are dismissed from the program. To enforce the policy, course directors email students who have a grade below 80% after every assessment.

Research Design

The research method used in this study was a qualitative thematic analysis based on descriptive phenomenology. The philosophy of phenomenology is the study of a phenomenon as it is experienced or lived by people, i.e., lived experiences (Sundler et al., 2019). In descriptive phenomenology, participants are expected to describe their lived experiences and the researcher brackets themselves from the meanings extracted from the text. Bracketing is the concept of setting aside one's preconceived ideas and biases and not imposing them on the meanings of participants' descriptions or interpretations (Reiners, 2012; Sundler et al., 2019). This lived experience is viewed in the life-world ontological and epistemological approach, originating from the writings of Husserl (Dahlberg et al., 2008). In this framework, experiences are understood in the light of the body and the lifeworld of the person, i.e., the participants' subjectivity. The goal of descriptive phenomenology is therefore to describe the universal essence — the common features of lived experiences of a group of people who undergo the same event or life situation, representing the true nature of the phenomenon experienced, while minimizing the researchers' own biases (Lopez & Willis, 2004).

Data Collection

An anonymous qualitative questionnaire with open-ended questions was designed to study the phenomenon of anatomy-related stress. The questionnaires were distributed to first-year OT and PT students at the end of a gross anatomy lecture roughly mid-way through their 10-week summer gross anatomy course. Participation in the study was voluntary, and no personally identifiable information was collected. Students dropped their completed questionnaires in a box at the rear of the classroom before leaving and the primary investigator collected these afterwards. The questionnaire asked participants to identify their program affiliation (OT or PT) and answer two open-ended questions. The questions asked were: (1) What do you find stressful in this current gross anatomy lecture coursework? and (2) What do you find stressful about the gross anatomy dissection and laboratory sessions? This study was approved by the University of Mississippi Medical Center's Institutional Review Board (IRB) as protocol UMMC-IRB-2022-35.

Data Analysis

Methods analyzing data in descriptive phenomenological studies use thematizing to describe the meaning of experiences (Braun and Clarke, 2006; Sundler et al., 2019). Themes derived from inductive thematic analysis are grounded in the data and experience of the participants (Braun and Clarke, 2006). The process requires reflexivity, where the researcher repeatedly questions their understanding of data and themes derived and seeks to understand the complexity of meanings rather than the frequency of their occurrence (Braun and Clarke, 2006; Sundler et al., 2019).

Semantic inductive thematic analysis for this data was conducted using the six-step process of reflexive thematic analysis described by Braun and Clarke (2006): (1) familiarizing yourself with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, (6) producing the report. Authors familiarized themselves with the data through repeated and active reading of responses. This allowed the identification of items of interest from the data, making connections between similar items, and generating relevant codes.

Following agreement on the initial codes among authors, the primary investigator analyzed these codes to create themes. The investigator ensured codes within each overarching

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theme properly fit with supporting data and performed an iterative analysis of the data and reflective reviews of themes created to arrive at the final themes. Two authors reviewed the final themes to ensure consistency and accurate reflection of the analyzed data. Analysis of data was done collectively for responses from both OT and PT students. However, in the iterative process, some differences between responses from either group were noticed. These are highlighted in the discussion where appropriate. The subsequent information is discussed under laboratory-related stressors and others (non-laboratory related stressors) encountered in gross anatomy.

Consistent with the methodology of qualitative thematic analysis, the researchers present their biases (Braun & Clarke, 2006). One member of the research team is an occupational therapist, the second is a general practitioner of medicine and surgery, and the third member is a non-clinical faculty member. All investigators are active anatomy educators and researchers in the field of professional healthcare education, including allied health, medicine, dentistry, and graduate education.

Results

Forty OT students and forty-nine PT students responded to the two open-ended qualitative questions in the questionnaire. Theme definitions, descriptions, and sample quotes from study participants and their affiliation (OT or PT) are described here. Fourteen themes were generated in response to both open-ended questions regarding stressors encountered in the laboratory and in the lecture component of the course. Seven of these themes were encountered in both the laboratory and didactic components of the course, while the other seven were specific only to the laboratory dissection component of the course (Table 1).

Stressor Theme	Where stressor was experienced	Course or curriculum specific*
Dissection supervision	Laboratory	Course
Dissection group dynamics	Laboratory	Course
Emotional preparation	Laboratory	Course
Fear of death	Laboratory	Course
Condition of donor	Laboratory	Course
Donor fat	Laboratory	Course
Quality of dissection	Laboratory	Course
Previous anatomy experience	Lecture and Laboratory	Curriculum
Anatomical terminology	Lecture and Laboratory	Course
Information	Lecture and Laboratory	Course and curriculum
Teaching styles	Lecture and Laboratory	Course
Fear of failure	Lecture and Laboratory	Curriculum
Self-directed readiness	Lecture and Laboratory	Curriculum
Time constraint	Lecture and Laboratory	Course and Curriculum

***Course:** Stressors directly related to the gross anatomy course (lecture and laboratory dissection); **Curriculum:** Stressors not directly related to the gross anatomy course, including those from the OT and PT curriculum, admission requirements/criteria, prerequisites, curriculum design, and other factors outside the scope of the gross anatomy course but within their plan of study.

Table 1. *Emergent themes from student responses and subcategories.*

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Laboratory-Specific Stressors

Laboratory-specific stressors in this study included: dissection supervision, dissection group dynamics, emotional preparation, fear of death, condition of donor, donor fat, and quality of dissection. A word cloud generated from codes used to develop the themes is shown in Figure 1.

"Dissection supervision" referred to the perceived inadequate numbers of anatomy faculty and teaching assistants to supervise students' dissection in the laboratory. Participants described this lack of adequate supervision during dissection as stressful to them. "I feel that if you do not get a professor to show up or teach you the structures directly, you may not be set up for success in this course." (PT 5), mentioned one participant. Another wrote, "I feel like we are kind of left to our own devices when dissecting." (OT 28).

The theme "dissection group dynamics" referred to the perceived incompatible experiences students within the same dissection team working on the same donor felt toward each other. These experiences were defined in terms of the different personalities, dissection experiences, and program differences (OT vs PT). "Not all lab members are as active during lab or after. I believe you get out what you put in, so personally, I feel like I have to put more stress on myself to keep my group up to date/pace with what we are dissecting." (PT 23). "In the lab, with the number of people per dissection table, there is always someone sitting out. PT guys are naturally more aggressive, so they are constantly pushing the girls to stand by. I do not feel like this class should be OT and PT. It should be specified to each." (OT 24).

"Emotional preparation" described the lack of emotional and mental preparedness for students before they began laboratory dissection. Participants expressed their psychological unreadiness to deal with being continuously close to an anatomical donor and the laboratory environment as stressful. One commented, "Being thrown into an emotionally and mentally trying environment without much warning . . ." (OT 29), and another described it as "Very daunting to be working with cadavers and mentally exhausting to dissect . . ." (OT 6).

The theme "fear of death" described students' stressful experiences in dealing with death including cutting a deceased person, previous experiences with death, and stress from being reminded about the death of close relations while in the laboratory, which made their dissection experience stressful. A student disclosed, "I have PTSD from watching a family member die in a wreck, and being close to a cadaver every day is very draining. I've started having nightmares again because of it." (OT 21). "The reality of cutting into a

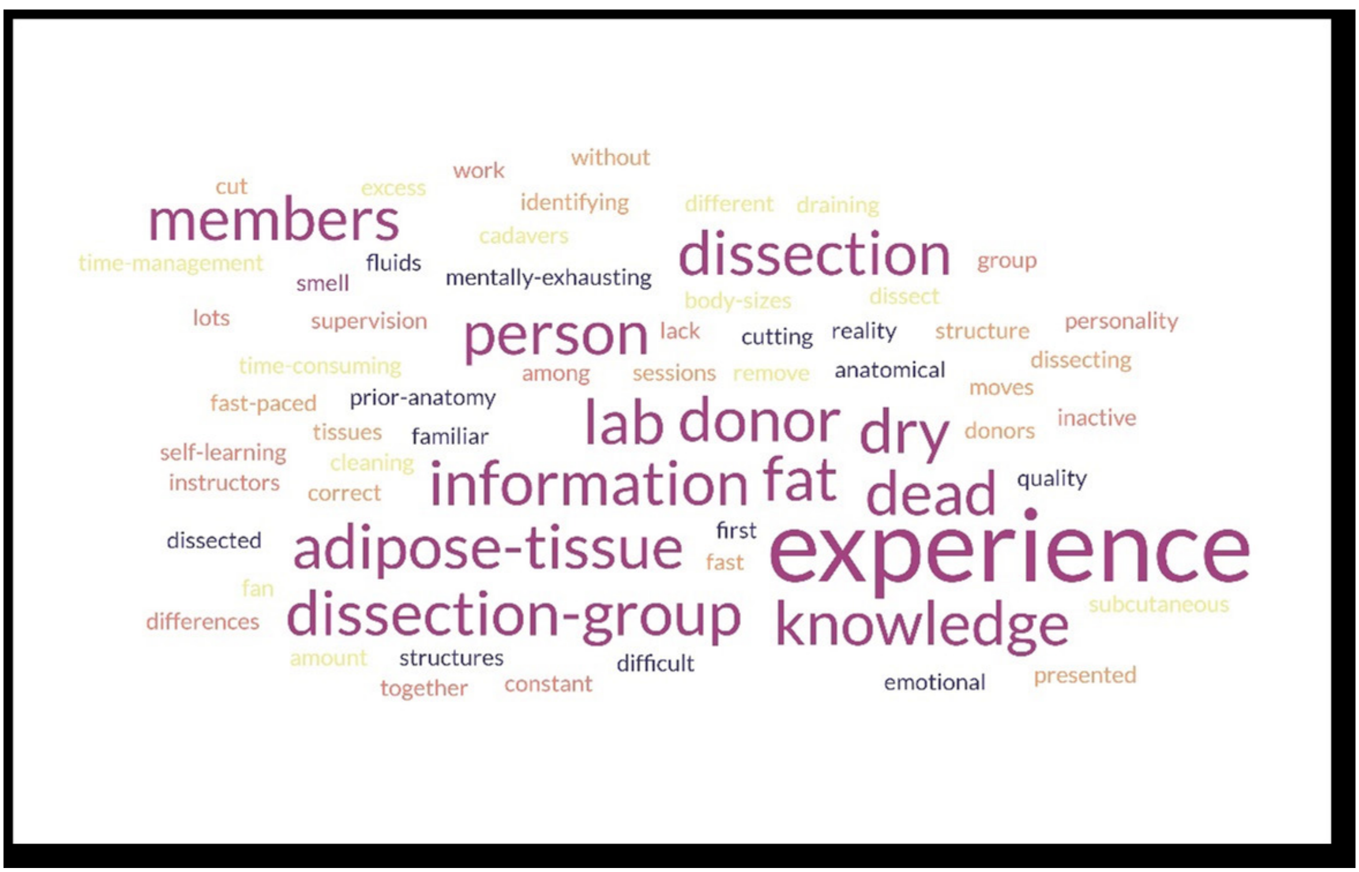

Figure 1. *Word cloud representing codes for laboratory-related stressors.*

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dead person is stressful." (OT 1). Participant PT 16 mentioned having "never experienced death before" as a stressor.

Participants described the appearance and state of the anatomical donors, their dryness or moistness, anomalies, donor body fluids, blood, and the smell of the donor as stressors. This was captured under the theme "condition of donor." One student revealed, "The smell is also very difficult to deal with. I almost fainted one day because of how strong it is." (OT 21). Others wrote, "When bodies start to dry, it is difficult to differentiate nerves from arteries." (PT 6) and "Some bodies have anomalies which make the dissection and quizzes harder." (PT 39).

The theme "donor fat" referred to stressors experienced by students from dissecting donors with greater amounts of adipose tissue. Their responses were centered on the amount of body fat they had to dissect through and the time it took working on this group of donors. Students expressed their experience as follows: "Our body has a lot of fat, so it takes extra effort outside of class to learn the material because our class time is taken up by trying to clean fat." (PT 6). "Respectfully, our body is bigger and more moist with adipose than others. It is a bit unfair that bodies around ours just cut superficial skin and they've found all their muscles and can get a jump start on learning them while we are still digging through adipose." (OT 31).

The theme "quality of dissection" referred to the perception of stress by some students to make perfect cuts and achieve flawless dissections during laboratory sessions. "The feeling of being perfect in dissection . . ." (PT 26) and "The requirement of good dissection skills to succeed . . ." (PT 19) were among the students' responses.

Non-Laboratory Specific Stressors

Non-laboratory specific stressors identified in this study were stressors students described they experienced in both the laboratory and didactic components of the gross anatomy course. These included the following themes: previous anatomy experience, anatomical terminology, information, teaching styles, fear of failure, self-directedness, and time constraints. A word cloud from the codes used to generate themes is shown in Figure 2.

"Previous anatomy experience" encapsulated responses that described a lack of previous dissection experience and perceptions of stress from students who lacked relevant anatomy coursework. Some mentioned, "Being a biology major and never seeing any of this material before is stressful." (PT 18). Another wrote, "For someone who has never dissected before, it is hard making a decision on the right way to go." (PT 16).

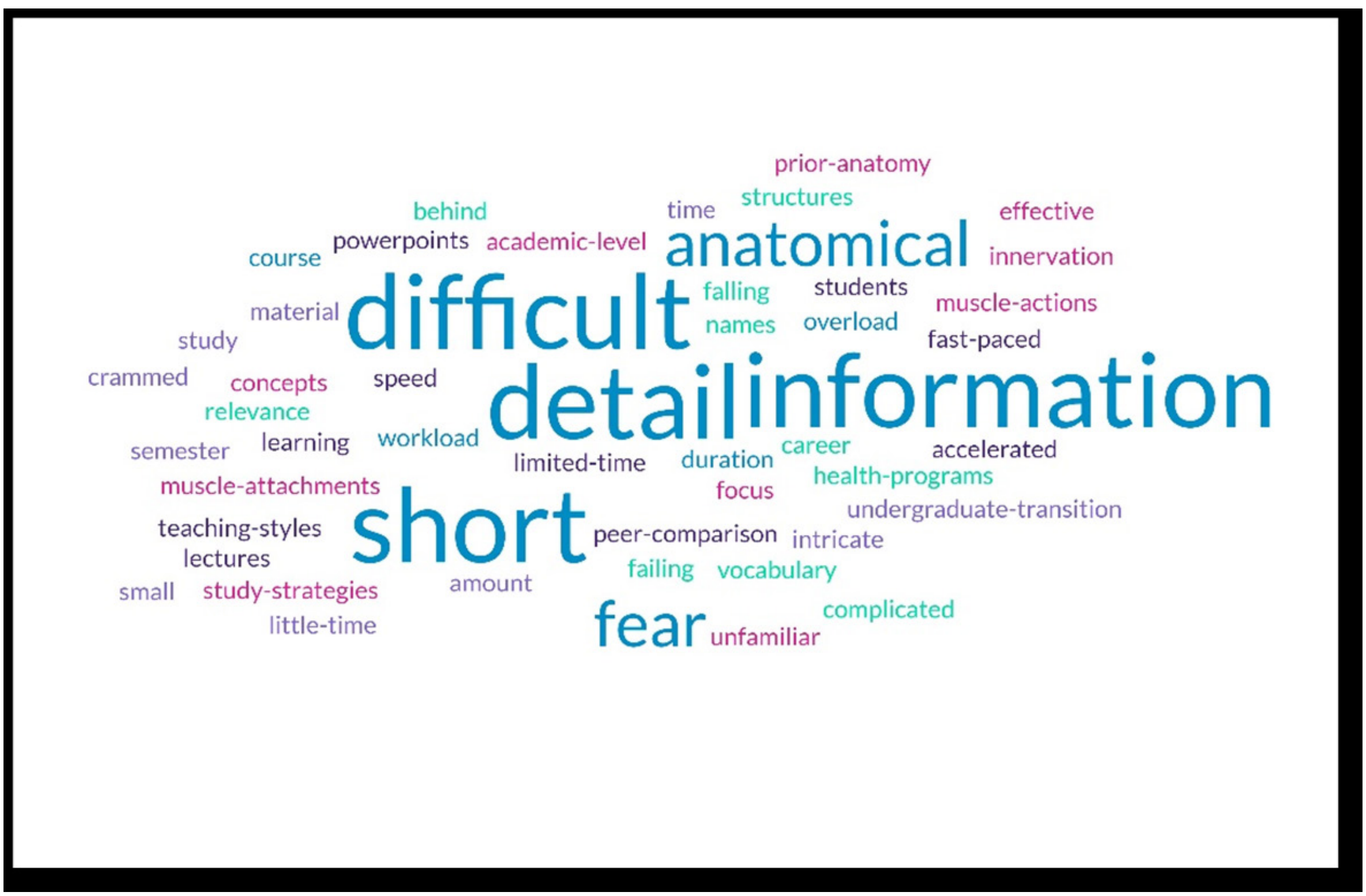

Figure 2. *Word cloud representing codes for non-laboratory stressors.*

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The theme "anatomical terminology" referred to the uniqueness of the language of anatomy as used in instruction. Descriptions of this included the complicated vocabulary in both the anatomy lecture and laboratory dissection, special anatomical terms including names of muscles, attachments, neurovasculature, and other body parts. "Terms are similar in the same areas. It is difficult to keep it straight, e.g., scapula, subscapularis, suprascapular, supraspinous fossa, etc." (PT 6) mentioned one student. "There are multiple different names for things, so that can be confusing." (OT 15) described another.

The theme "information" referred to the volume and the detail of information delivered and required in both the anatomy lecture and laboratory dissection components of the course. Sample comments included: "There's always a big agenda in a small-time frame." (PT 21), "It is like drinking from a fire hydrant." (OT 8), and "There are 45–90 PowerPoint slides per day, and we are expected to learn these slides fully each day." (OT 35).

"Teaching styles" referred to the variability in teaching styles of the different professors, including their presentation formats, lecture delivery, use of teaching aids, and approach to teaching and answering questions in the laboratory. "Changing different professors from week to week is stressful to get readjusted to each teaching style." (OT 20). PT 25 wrote, "Some teachers are better at breaking things down, whereas some are not," and OT 26 stated, "I hate being quizzed in the lab when I ask a question. I am asking a question because I don't know the answer. I need confirmation, not additional questions."

"Fear of failure" described stressors participants felt by either comparing themselves to their peers, failing the course, keeping up with faculty expectations of mastery, or from their awareness of the usefulness of anatomical knowledge in their career. Students mentioned repeated administrative emails about their risk of failing for scores below 80% in the overall course as stressful. Participant OT 3 wrote, "Also, that a 'C' is not okay for the most part and that almost every week they email you, saying you better be aware and doing something. I am aware of my grade and I'm doing everything I can. All the emails do is make me more stressed and feel like a dumb student. I don't think having a 79 is the end of the world… it's just one point from 'B,' they make me feel like I am a failure." Participant OT 1 described "The comparison of other classmate's success or difficulty" as stressful. Finally, participant PT 18 mentioned, "Knowing that you need to actually learn the material to use for the rest of your career and not just memorizing for the test" is stressful.

The theme "self-directedness" described students' ability and readiness, and preparedness to take responsibility for their own learning. Participants expressed it as stressful not knowing how to study, manage their time, or not being fully prepared to deal with the academic demands of professional school coming from an undergraduate program. PT 25 wrote, "I don't know how to efficiently and effectively study the amount of material in such a short time period." "Honestly, it's the hardest level of schooling any of us have thus far, so finding the most effective studying to cater to that is just difficult. Not unable to do it, just difficult," described OT 17.

The final theme, "time constraints", referred to stressors students experienced in learning anatomy because of the limited time available for the entire course, and the disparity between the allotted time and volume of material. Their 10-week summer gross anatomy course is the first in their curricula. Participant OT 3 mentioned, "I don't understand why all of this has to be crammed in two months. Should teach it in Fall semester." Participant OT 22 stated, "There is not enough time to study everything thoroughly before the quizzes each week. They keep bringing my grade down and I am not dumb. I know the material. I just need more time to learn it before I am quizzed on it." Another added, "Not necessarily the complexity of the material, but the speed that the course goes was challenging to become acquainted with." (PT 14).

Discussion

The findings of this study offer several insights into anatomy education by identifying several laboratory-specific and non-laboratory-specific stressors experienced by a group of allied health students taking gross anatomy. Previous studies have mostly described the associated symptoms experienced by students taking gross anatomy dissection-based courses, with a few highlighting what was responsible for those experiences (Grochowski et al., 2014; Lester et al., 2010). Most anatomy-specific stressors identified in this study were noteworthy and pointed towards either a course or curricular design issue, with some being compounded by personal factors. Importantly, most of the stressors identified in this study could be potentially modified either at the course level or curricular level. Addressing them may reduce the perception of stress and its impact on the students within the course. An awareness of these stressors identified in the present study could allow anatomy faculty to be mindful during revisions and work towards improving modifiable stressors as well as clarify students' understanding of non-modifiable ones.

Participants in this study perceived the composition of their dissection group as a stressor. Dissection groups consisted of four to five students who were randomly grouped, blending students of different genders and programs of study. A few of the female participants in this study reported a feeling of being sidelined by their male colleagues in the same group and reported having to find extra hours outside laboratory time to revisit the material. This finding is of note because there are not many reports of gender-related concerns in anatomy dissection groups. Moss-Racusin et al. (2012) described finding a preexisting subtle bias against women by science faculty members, and how female students were viewed as less competent than their male counterparts.

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Both faculty and students should be mindful of any hidden biases and opinions concerning gender roles during anatomy dissection. Better efforts should be made to help all students feel welcomed and valued in the dissection laboratory.

Another contributing factor to the stressor of dissection group dynamics was personality differences between students in the same dissection group and how these differences affected their dissection experience. Macalady (2021) reported that personality types influenced co-teaching relationships, with similar personalities reporting better collaboration, higher engagement, and increased job satisfaction. However, Neumann et al. (1999) revealed improved performance through diverse psychological types within the same learning group, even though Varvel et al. (2004) reported no difference in a similar study. Working effectively in a group with different personalities is a useful skill for health professionals because of the interdisciplinary approach to healthcare management (Taberna et al., 2020). Further studies into the various personality types and their effects on anatomy performance and intergroup communication may be needed.

The data on dissection group dynamics also showed that there were some compatibility issues in the dissection groups based on program affiliation (OT or PT). Some OT students reported being stressed by partnering with PT students on the same donor. A few others also mentioned how some PT students were aggressive in their dissection approach. Some OT students in this study mentioned they would prefer being taught anatomy uniquely to their OT group. However, there were no such reports from the PT students. This reflects previous findings and recommendations of practicing occupational therapists on teaching anatomy as a standalone course to OT students (Latman & Lanier, 2001; Schofield, 2014, 2018).

Beyond group dynamics, the quality of dissection was reported as a stressor. Even though the quality of dissection was not graded in this present study, some students mentioned a need for perfection in their dissection. This desire for perfection may be driven by personality type, individual preference, or the level of the student. Although these responses did not indicate that the perception of the quality of dissection influenced the group dynamic at the donor table, there is the potential for it to compound the already identified issues at the group level, requiring more explicit instruction and expectations to be given during dissection. One student reported, "The feeling of being perfect in dissection. Stressing the point of not being perfect will be very helpful." (PT 26). In anatomy courses where the quality of dissection is graded, this stressor could be prevalent.

Differences in students' previous anatomy experience observed in this study reflect some views of earlier research into the relevance of prior experience in anatomy. Two different studies by Jordan et al. (2014) and Kondrashov et al. (2017) showed that students without prior experience in anatomy mostly perceived previous anatomy experience as being more beneficial than those with prior experience. A significant difference in performance by students with prior anatomy experience that included a dissection component was reported by Jordan et al. (2014). However, Robertson and colleagues (2020) showed that prior experience in anatomy did not significantly affect students' performance in their current anatomy course. They concluded that the benefits of previous anatomy exposure could be less perceptible in terms of grades and more pronounced in other factors such as lower perception of stress, more time to dedicate to other courses, and overall increased quality of life. These differences in relevant anatomy coursework may be modifiable at the curricular level, where prerequisite decisions are made for programs.

Another anatomy-related stressor observed in this present study was dissection supervision, which students found lacking. Although students had access to dissection manuals for guidance, the findings from this study highlight the importance of combining these resources with explicit definitions of student roles in the same dissection group. One student reported that "Gross anatomy lab is stressful with everybody and every group being at different places on the cadaver." (PT 31). With explicit student roles, students within the same dissection group may work together in a better way than when left to decide among themselves what needs to be done.

In this study, each laboratory session lasted three hours and had four to five faculty members and a graduate teaching assistant supervising 90 students. This created a faculty-to-student ratio of one faculty member to fifteen students (3–4 donor tables). Students in this study described experiencing a lack of confidence in dissection and uncertainties in identifying structures, after sometimes being left to their own devices. Previous studies have shown that poor dissection experiences in anatomy affected students' confidence in anatomy knowledge and performance (Farey et al., 2018; Thompson & Marshall, 2020). Fixing this gap in supervision would require more trained anatomists to help supervise students taking gross anatomy dissection. Yet, Edwards et al. (2022) anticipate a further reduction with the retirement of anatomy educators overtaking the number of graduates enrolled in gross anatomy programs within five years. This could worsen the current faculty-to-student ratio, as observed in this study. Responses from this study also showed that some students expected to have faculty members at their dissection table for most of the laboratory period. These incorrect expectations can be addressed through proper orientation and definition of roles and expectations to students before and during their laboratory sessions. Also, faculty could consider options for accountability for students' roles and expectations.

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Similar to reports from Evans and Cuffe, (2009) and Manyama et al. (2016) regarding the impact of faculty shortage in anatomy education, participants in this study mentioned arranging extra laboratory sessions with near-peer tutors—students in second or third years who had already completed this course. This meant that students spent extra time beyond their regular contact hours to grasp what had been previously taught in the laboratory, worsening their perception of anatomy-related stress. Unfortunately, most students who could act as near-peer tutors have personal academic responsibilities that prevent a continual reliance on them as an answer to the inadequate faculty supervision experienced in anatomy education.

Findings from this study also suggested that students in this anatomy course described being emotionally unprepared for the dissection experience, including their discomfort with death. Emotional unpreparedness and fear of death are reported in the literature concerning anatomy-related stress and linked to avoidance behaviors in anatomy dissection (Allison et al., 2021). Responses reflecting fear of death mentioned the emotional stressor of cutting a deceased person, while others described how their experience with anatomical donors rekindled emotions of past traumatic events in their lives. Some participants described having nightmares and fainting spells after starting dissection, similar to the findings of Finkelstein and Mathers (1990).

As observed in this study, students with histories of traumatic life events related to death and dying could be at an emotional disadvantage in a cadaveric-based dissection course and may require extra emotional preparations or some accommodations. Such students may still benefit from emotional preparations before and after laboratory sessions (McGarvey et al., 2001). Earlier studies have shown improved levels of anxiety and stress, intrinsic motivation, and performance in students following the introduction of a pre-laboratory dissection module (Bertman & Marks, 1989; Chaudhuri, 2021). Faculty should be mindful that not every student entering the dissection laboratory may be psychologically fit to do so and may address this potential stressor by introducing similar pre-laboratory modules as described by Bertman and Marks (1989) and Chaudhuri (2021).

Participants in this study also mentioned the amount of their donor's adipose tissue as a stressor to their dissection experience. Students described dissecting donor bodies with more adipose tissue as stressful because it took longer and kept them behind schedule. These findings share some similarities to those reported by Goss et al. (2020) about how students described dissecting anatomical donors with more adipose tissue as difficult, requiring extra work, time-consuming and frustrating. In the present study, some participant responses and descriptions of their donors' adipose tissue and its impact on their studies could reflect anti-fat biases or fatphobia within this student population, though further studies would be needed to verify this.

Reports of weight bias and stigma on the quality of healthcare given to obese patients by some practitioners in both OT and PT are prevalent in the literature (Alperin et al., 2014; Elboim-Gabyzon et al., 2020; Friedman et al., 2022). Faculty could use this initial anatomy experience to redirect students' perception away from developing or strengthening any negative attitudes towards obese patients. The distribution of subcutaneous fat and visceral fat in donors in the anatomy laboratory could be great learning resources. Rather than perceiving it as a waste of dissection time, students could approach these donors through an inquiry-based lens to learn more and appreciate the anatomical difference in the distribution of subcutaneous and visceral fat, linking them to clinical importance. This is important because as students get exposed to the internal and external anatomy of donors, there is the possibility this initial encounter for novice dissectors could engender negative attitudes, including depersonalization, dehumanization, or ridicule of donors by focusing on their unexpected anatomical features (Hafferty, 1988, 1992).

Students in this study also described how anatomical terminology was complicated and similar, and how anatomical structures could have multiple names. Anatomical terminology is used to reflect the unique language in health education. This inherent language of anatomy is part of its intrinsic identity, reflecting the intrinsic cognitive load in its instruction. Anatomical terminology presents itself as a non-modifiable stressor in anatomy education. However, it is not clear from these responses whether students' descriptions of difficult anatomical terminologies and structures having multiple names implied the use of eponyms as alternate names. Eponyms are common in anatomical literature and can be seen as contributing to the cognitive load imposed on students (McNulty et al., 2021), although others argue differently (Ghaznavi, 2021). Further investigation would be required to explore whether students' perception of anatomical terminology as a stressor is linked to the use of eponyms or not.

Additionally, participant responses on information, course duration, and teaching styles concerning the variations in presentation and how anatomy lectures were presented can be tied into the concept of extraneous cognitive load. Extraneous load is described as the excessive processes that do not contribute directly to the learning process, including resources devoted to processing the information presented (Jordan et al., 2020; Van Merriënboer & Sweller, 2010). In addition to the 45–90 PowerPoint slides per day previously raised as a concern by OT 35, another student (OT 12) mentioned, "Some instructors teach fast, and some teach just right. Some instructors are more detailed when teaching, so those seem to really stick. I feel like I have to study a lot more when instructors rush through the PowerPoint slides." Participant OT 16 mentioned, "PowerPoint slides are not concise, there are too many words under each bullet point."

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In contrast to intrinsic cognitive load that cannot be altered through instructional interventions without affecting the structure of the task to be learned, extraneous cognitive load may be imposed by instructional methods (Van Merriënboer & Sweller, 2010; Young et al., 2014). Intrinsic and extraneous cognitive loads are additive, and information overload results when the sum of the intrinsic and extraneous cognitive loads surpasses working memory and capacity (Van Merriënboer & Sweller, 2010; Young et al., 2014). This can happen when the anatomy to be learned becomes particularly complex (Van Merriënboer & Sweller, 2010). Recommendations to improve cognitive overload include reducing extraneous loads, especially in learning that involves complex tasks, or where this reduction is inadequate, reducing the intrinsic load to create more room and processing resources for learning (Van Merriënboer & Sweller, 2010).

Consistent with previous studies (Alabduljabbar et al., 2022; Beran, 2015), participants in the present study demonstrated a fear of failure, including stressors from peer comparison and faculty expectations. This dispositional tendency to avoid failure is high among health professional students and could adversely affect their mental well-being and performance (Alabduljabbar et al., 2022). Mental well-being programs and wellness week campaigns are continually needed to remind students of the benefits of reducing the urge for competitiveness and setting personalized and achievable academic goals.

A noteworthy finding in this study that is commonly seen in health-related educational programs is the lack of self-directed readiness among students. Effective self-directed learners determine their own goals and use a variety of key self-regulated learning processes to achieve these self-identified goals (Brydges et al., 2010; Husmann et al., 2018). Responses from some participants in this study indicated they did not know how to go about their studying, or which study strategies they could use when learning anatomy. Others also described being unprepared for the rigors of professional school, citing that it was a huge transition for them from the undergraduate level. Students described difficulty in triaging their learning goals and their desire to know how best to direct their learning. Self-directed learning readiness is critical in the development of lifelong learning and is an integral part of health professionals' education and the development of professional competence (Babenko et al., 2017; Yang & Jiang, 2014). Incorporating opportunities for students to improve their self-directed learning skills could be beneficial, as students would know how to set their learning goals, choose resources, and better navigate their learning process even amid the higher volume of information and time constraints, commonly observed in most healthcare education programs.

Limitations of the Study

The curricular placement of this anatomy course at this study site is ten weeks in the summer and may not accurately reflect the general picture of anatomy programs and duration at other institutions. OT and PT students were co-taught anatomy, which could have contributed to the phenomenological descriptions of some students. In other institutions where this teaching method is not practiced, students may not report stressors from the co-teaching perspective. The individual differences in vulnerability and perception of stressors, especially among individuals with preexisting relatable traumatic experiences, could have affected their description and report.

Future Directions

Future improvements of this study could involve other allied health sites where anatomy is both co-taught and siloed. This will enable researchers to explore which stressors are not confounded by the method of instruction. Further studies could explore these stressors from the OT or PT perspective uniquely, to see any differences in anatomy-specific stressors as uniquely experienced by each allied health group. Due to the differences in perception of stressors, future studies could longitudinally explore whether students' perceptions of anatomy-specific stressors impacted their performance in gross anatomy by comparing their performance in both laboratory dissection and lecture components of the course. This could allow further insight into which stressors affect performance to the greatest extent and allow opportunities for modifying them. Finally, because anatomy is a component of most health-related programs, further studies using a Q-sort could be conducted among other health professional students to explore how students to rank their experience with these stressors. Q-methodology allows us to identify and describe the shared viewpoints that exist on a topic, revealing areas of consensus and disagreement across these views (Coogan & Herrington, 2011). This would be a more robust way to examine any patterns in the reported opinions of students.

Conclusion

This study was designed to investigate what students found stressful in their gross anatomy course besides the commonly reported fear of death in the literature. This qualitative thematic analysis showed other laboratory-specific and non-laboratory specific stressors. While most laboratory-specific stressors were donor-related, others revolved around non-donor issues, such as dissection group dynamics and supervision. Students in this study described as stressful how they were paired with others, their inadequate supervision, lack of emotional preparation, prior anatomy experience, and other donor characteristics as stressors in their gross anatomy study.

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Based on these findings, the authors recommend incorporating a pre-laboratory module to prepare students emotionally and mentally before they start dissection. Certain stressors were prominent in some students because of their personal experiences with tragedy and death. It may help to have processes in place where students with pre-existing traumatic experiences can anonymously request extra emotional preparation or accommodations to deal with the impact of learning in a cadaveric-based environment. Also, assigning and providing explicit directions for student roles in the dissection group and providing better guidelines for the dissection group dynamics may facilitate collaboration. Additionally, students should be reminded that anatomical donors are like the patients they would see in practice. As such, anatomical donors would have different physical characteristics and students must honor each donor respectfully, regardless of their physical characteristics. Students must be encouraged to approach donor dissection free from any biases concerning the donor's physical characteristics. The authors hope that, based on the findings of this study, additional investigations into the impact of these stressors and interventions to mitigate those that are potentially modifiable can be made by applying some of the recommendations.

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About the Authors

Oheneba Boadum, MBChB, MA, MS, is an assistant professor in the Department of Advanced Biomedical Education, and Director for Simulation and Interprofessional Education at the University of Mississippi Medical Center, in Jackson, MS. He is a general practitioner of Medicine and Surgery. His educational research interests are in mental well-being in education, self-directed learning readiness, and learning strategies. He teaches gross and developmental anatomy, medical neuroscience, and histology to medical, dental, and OT and PT students. Audra Schaefer, PhD, is an associate professor in the Department of Advanced Biomedical Education, and the Assistant Dean for Academic Affairs in the School of Graduate Studies in the Health Sciences at the University of Mississippi Medical Center in Jackson, MS. She teaches neuroscience, histology, and educational research methods. Her research includes metacognition, learning strategies, and training of anatomy educators. Ellen M. Robertson, PhD, OTR/L, is an assistant professor in the Department of Physician Assistant Studies at Randolph-Macon College in Ashland, Virginia. She is an Occupational Therapist. She teaches gross anatomy and neuroscience to physician assistant students and her research interests are in health professional education, student support, and wellbeing.

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Answer Changing Behaviors and Performance in a First-Year Medical Gross and Developmental Anatomy Course

Marli Crabtree, MS[1], Kenneth L. Thompson, PhD[1], Ellen M. Robertson, PhD, OTR/L[2]

[1]Department of Advanced Biomedical Education, University of Mississippi Medical Center, Jackson, MS, USA

[2] Department of Physician Assistant Studies, Randolph-Macon College, Ashland, VA, USA

Corresponding author: ellenrobertson@rmc.edu

Abstract

Research has suggested that changing one's answer on multiple-choice examinations is more likely to lead to positive academic outcomes. This study aimed to further understand the relationship between changing answer selections and item attributes, student performance, and time within a population of 158 first-year medical students enrolled in a gross and developmental anatomy course at an academic medical institution in the United States. For each student, answer changes, overall exam performance, and individual item performance data were retrieved from an online testing software for a single block exam. Researchers determined how many times students changed their answers, the associated outcomes, and time spent on each item and the entire exam in relation to item performance. Students in the highest performing quartiles were more likely to keep their initial answer selection, spent more time choosing their initial answer selection, and averaged a higher total exam time than each of the lowest two performance quartiles. Time on individual items and answer changes had a statistically significant relationship, with more time relating to the presence of an answer change. Changing an answer selection was more likely to result in a negative outcome. The content subject was significant in relation to answer changes and time spent per item. This study provides a deeper understanding into which factors, such as item attributes, time, and performance of the student, showed statistically significant relationships to answer changing. https://doi.org/10.21692/haps.2024.008

Key words: changing answers, test-taking practices, developmental anatomy, gross anatomy, medical education

Introduction

Answer Changing Research

As early as 1929, Mattews found that 86% of college students believed that changing their answer led to an overall negative outcome, and, in 1984, Benjamin et al. similarly found that 55.2% of faculty believed that changing their answer would lead students to a negative outcome. This belief has been seen across decades and is still present in classrooms today (Benjamin et al., 1984; Cox-Davenport et al., 2014; Merry et al., 2021).

Much of the existing literature observes nursing, psychology, and undergraduate student populations, with fewer studies observing medical and dental students. Ultimately, the studies that did observe these professional degree students came to similar conclusions. In 2017, Pagni et al. found that 99.4% of dental students in their study benefitted from answer changing. Ferguson et al. (2002) studied second-year medical students and the impact of answer changes on their performance in a foundational science course and concluded that changing one's answer from the initial selection resulted in a significant positive change. Answer-changing research in the medical student population has varied in their aims, with some addressing the impact of personal preferences like learning styles on answer changing and others strictly observing the outcomes associated with changing an answer (McNulty et al., 2007; Merry et al., 2021). Similar to other student populations, this research has shown that changing answer selections is most commonly beneficial, but because of the various study designs and aims found in existing literature, more research is needed to better understand the answer changing behaviors of medical students.

Factors Related to Answer Changing

Although research on answer changing behaviors exists, and the outcomes regarding answer changing are fairly consistent, there is less understanding and agreement regarding the

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factors that relate to the presence and pattern of answer changes. Over time, researchers have hypothesized that factors like student proficiency in the associated courses and/or on the associated exams, item attributes, the order of questions and time allotment, and other possible variables could be influencing students to exhibit the answer changing behaviors they do (Ferguson et al., 2002; Geiger, 1997; Harvill & Davis, 1997; Liu et al., 2015; Mueller & Wasser, 1977; Ouyang et al., 2019; Pettijohn II & Sacco, 2007).

Earlier studies that addressed the impact of student proficiency on answer changes had varying outcomes, with some showing statistical significance and others showing insignificance between the behaviors of the highest and lowest performing students (Ferguson et al., 2002; Friedman & Cook, 1995; Mueller & Wasser, 1977). A study completed in 2021 concluded there were no indications that students of different proficiency levels were more likely to benefit from or be harmed by answer changing, and multiple older studies provided the same conclusions (Archer & Pippert, 1962; Matthews, 1929; Merry et al., 2021). Contrastingly, a study completed by Ouyang et al. (2019) considered student proficiency and found the opposite. This study divided students into higher, medium, and lower academic ability groups based on their performance on a high-stakes exam. Students who were determined to be of higher academic ability were found to review more items, were less likely to change answers, and were more likely to make an incorrect to correct change than students of lower academic ability (Ouyang et al., 2019). Other studies have also found that answer changes were more beneficial to higher performing students (Ferguson et al., 2002; Harvill & Davis, 1997). Item attributes, such as the presence of a picture, subject content, and recency of the content used (material in the current block or review material from previous blocks) have been less commonly studied in relation to answer changing.

The relation between time and answer changing was considered by Ouyang et al. (2019). The researchers found that time taken on an item had significant relationships with pattern of change and varied between students with different proficiency levels (Ouyang et al., 2019). This study found that students spent the most time on correct to correct changes (presumably, changes from correct to incorrect and then another change from incorrect to correct) followed by incorrect to incorrect changes (Ouyang et al., 2019). Further, students in this study spent the least amount of time on correct to incorrect and incorrect to correct changes (Ouyang et al., 2019). In 2002, Ferguson et al. found that higher item times were significantly related to the presence of an answer change, with more time resulting in a higher likelihood of an answer change. The authors found no other studies that researched the relationships between time spent on each individual item in relation to the presence and pattern of answer changes. Likewise, few studies expanded beyond correct to incorrect, incorrect to correct, and incorrect to incorrect patterns of change students made on individual items (Ouyang et al., 2019).

Goals of this Study

This study aimed to fill a gap in the existing literature on answer changing behaviors. Looking at first-year medical students in a gross and developmental anatomy course, this study aimed to observe the presence, patterns, and outcomes of answer changes in relation to specific item attributes on a multiple-choice exam. This study dove deeper into patterns of answer changes, looking at not only single changes but also multiple answer changes. Another aim of this study was to determine if time spent on individual items and the exam as a whole was related to the presence and pattern of changes made by students. Comparatively, the researchers also aimed to identify differences in the answering behaviors of high and low performing students.

Materials and Methods

This study was approved by the Institutional Review Board (IRB) at the University of Mississippi Medical Center, UMMC-IRB-2022-356.

Educational context

This retrospective and descriptive study was completed using data from an academic medical center in the southeastern United States. The gross anatomy (GA) and developmental anatomy (DA) course was region-based and organized into content blocks. Block one covered the back and upper limb, block two covered the thorax and abdomen, block three covered the pelvis and lower limb, and block four covered the head and neck. Anonymous performance data was obtained and studied from the third block summative multiple-choice exam for 158 students enrolled in their first year. The block three exam was the only assessment observed in this study. Because of software and data limitations, only one exam could be observed. The third block exam was chosen due to its number of review and image items, as well as the broad array of anatomical content covered in the pelvis and lower limb block (musculature, vasculature, neuroanatomy, organs, soft tissues, and bony elements).

The third block exam was administered synchronously on campus using the exam-taking software ExamSoft (https://examsoft.com/). The exam was proctored and completed on students' personal devices within a locked browser. ExamSoft logged the activity of each student who took this exam electronically, creating data that provided time stamps, movement between questions, answer changes, and outcomes for each item. Students were allotted a total of three hours or 180 minutes to complete the exam. Although there was no access to student accommodation information to determine whether any students were approved for extra exam time, all students in this study completed the exam within the standard 180-minute time limit. Consequently, potential accommodations were not considered as criteria for exclusion. Students who completed the exam on paper were excluded from the study, as were three graduate students enrolled in the course.

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This block exam consisted of 100 questions. Three questions were excluded due to the items being omitted before final grades were calculated, leaving a total of 97 questions used in data analysis. Of the 97 items, there were 65 GA and 32 DA questions. The items were a mix of first and second order items, with some being in the form of clinical vignettes. Nineteen questions incorporated images. The image-based questions consisted of radiology imaging, cross-sectional anatomy, DA depictions, and questions based on diagrams or clinical imagery. The exam also incorporated review content from previous blocks, consisting of 16 total review items, nine covering GA content and seven covering DA content. All review items were newly crafted questions, and none were exact copies of questions students had seen on either of their two previous exams. The course director and instructors completed an extensive review of the exam items and removed all negatively coded and worded items before the exam was distributed to students. All items in this exam had four answer options, and none of the options were "all of the above" or "none of the above."

Data collection

For each student, an exam activity report was downloaded from ExamSoft that contained time stamps, navigation between questions, answer changes, and outcomes for each item. Activity data were then de-identified by removing all student identification numbers and assigning each student a random number from five to 163. The data for each student were then combined and stored within IBM SPSS (Statistical Package for the Social Sciences) Statistics for Windows (2020, Version 28), where all data analysis was later completed. The data collected and observed from ExamSoft included the individual answering behaviors of each student.

Answering behavior

The specific student answering behaviors observed were the correctness of their initial answer selection, presence of a change or no change to their initial answer, the pattern of change, if any, and associated outcome, either correct or incorrect. In addition, the amount of time the student spent per item and the total time spent on the exam were determined. The determination of the time spent on each item, time spent on the total exam, and answer changes made were completed using the exam activity reports produced by ExamSoft.

The final response for each item was categorized as not changed (the student kept their initial answer selection) or changed. Additionally, the pattern of change for each item was determined as one of the following: no change in answer (0), change from the correct answer to an incorrect answer (1), change from an incorrect answer to the correct answer (2), change from an incorrect answer to a different incorrect answer (3), multiple changes (initial answer choice was correct or incorrect) ending with the correct answer (4), or multiple changes (initial answer choice was correct or incorrect) ending with an incorrect answer (5).

The correctness of each item was determined using an answer key and the activity report for each student. For each item, a timestamp was recorded documenting the time at which the student navigated away from the item. To determine the time on an item, the time at which the student navigated away from the previously visited item was subtracted from the time at which the student navigated away from the current item. If a student revisited an item, the time spent on each revisit was added to the total item time. Total exam time for each student was calculated by subtracting their start time from their submission time. Total exam times were rounded to the nearest minute. Item times were reported in either seconds only or minutes and seconds (minutes.seconds), which will be explained where relevant.

Item Attributes

Data regarding item attributes included the recency of the content (if the item was current block material or review content from a previous block), the subject content of the item (DA or GA), and whether the item utilized a picture or only consisted of words. To determine item attributes, a blank copy of the exam was observed and attributes for each item were recorded. This categorization was completed by the first author, and once completed, reviewed by the last author to confirm accuracy.

Data Analyses

Statistical analysis was completed using multiple statistical methods with the alpha value set to 0.05 for all statistical tests used. For the purposes of this study, the mention of significance is referring to statistical significance. A mix of chi-square tests of independence, independent samples t-tests, and analysis of variance (ANOVA) tests was used for data analysis and will be discussed where the respective results are reported.

Results

Descriptives

Students were classified into quartiles based on their total exam performance on the third block exam. All exam scores reported are in the form of percentages, with a minimum of zero and a maximum of 100. Total exam scores ranged from 53-94, with quartile four (Q4) being the lowest performing students and quartile one (Q1) being the highest performing students. The average times spent per item and on the total exam were calculated for each quartile of students. Student quartiles were used to determine differences in answering behaviors. The range of exam scores used to determine the quartile each student was categorized into can be found in Table 1.

Quartile Differences

An ANOVA compared the time per item to each performance quartile, and this relationship was found to be significant (F (3, 15,419) = 6.788, $p < 0.001$). Item time averages and ranges for each performance quartile can be found in Table 1. Because the ANOVA assumption of homogeneity of variances was violated, a Games-Howell post-hoc correction was used to identify

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significant differences between quartiles. Time spent per item was significant when comparing Q4 and Q2 ($p < 0.001$), with an average difference of eight seconds. Time spent per item was also significantly different by 5 seconds when comparing Q3 and Q2 ($p = 0.025$).

An ANOVA was also conducted to test the relationship between performance quartile and the total time spent on the exam. The ANOVA identified a significant difference (F (3, 15,419) = 115.658, $p < 0.001$). Exam time ranges and averages for each performance quartile can be found in Table 1. A Games-Howell post-hoc correction identified significant differences in average exam times between each quartile (p < .001).

To analyze the relationship between the performance quartile and both the presence and pattern of change, a chi-square test of independence was used. The relationship between performance quartile and the presence of an answer change was significant (X^2 (3, N = 15,423) = 92.496, $p < 0.001$). Quartile one logged the highest number of answers that had not been changed. Conversely, Q4 averaged the most answer changes. Quartiles two and three were similar in that both groups changed their answer more often than keeping their initial selection. Quartile one was the only quartile that kept their initial selection at a higher rate than changing their answer.

There was also a significant relationship between the performance quartile and the pattern of change made (X^2 (15, N = 15,423) = 102.213, $p < 0.001$). Quartile four, the lowest performing quartile, logged the most changes from correct to incorrect compared to all other quartiles. Furthermore, Q4 had the highest number of multiple answer changes ending with an incorrect selection, with nearly two times as many of these changes when compared to Q1. Multiple answer changes to the same item were most beneficial to Q1. Quartiles two and three were similar in logged answer-changing patterns, showcasing nearly identical numbers of incorrect to correct answer changes and multiple changes ending with an incorrect answer.

Time and Item Attributes

ANOVA indicated a significant difference between the time spent on an item and the pattern of change (F (5, 15,417) = 552.001, $p < 0.001$). The average item times associated with each pattern of change are presented in Table 2.

Quartile	Score ranges	Item time average (sec)	Item time ranges (min.sec)	Exam time avg (min)	Exam time ranges (min)
Q1	83-94	63	00.03-32.35	108	47-177
Q2	78-82	67	00.03-15.19	112	66-180
Q3	74-77	62	00.03-16.38	104	38-180
Q4	53-73	59	00.02-12.36	100	38-180

Table 1. *Quartile differences: score ranges and item and exam time averages and ranges.*

	Item time average (min.sec)	P-value
Pattern of change		< .001
No answer change	0.51	
Correct to incorrect	2.03	
Incorrect to correct	0.45	
Incorrect to incorrect	2.02	
Multiple changes, end correct	2.29	
Multiple changes, end incorrect	0.54	

Table 2. *Presence and pattern of change in relation to average item and total exam times*

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Using an independent samples t-test, a significant relationship was found between time spent on each item and the correctness of the final answer selection (t (15,421) = 23.118, $p < 0.001$). The assumption of equal variances was violated based on the Levene's Test ($p < .001$). The average item times for these relationships are presented in Table 3.

An independent samples t-test analyzed the significance between the time spent on an item and item attributes, including the presence of a picture, subject content, and recency of the content. Significance was determined between item time and the presence of a picture (t (15,421) = 9.123, $p < 0.001$). The assumption of equal variances was violated based on the Levene's test ($p < 0.001$). Additionally, significance was determined between item time and subject content (t (15,421) = 33.870, $p < 0.001$). The Levene's test indicated that the assumption of equal variances was violated ($p < 0.001$). In contrast, item time was not significant in relation to the recency of the item content (t (15,421) = -.400, $p = .694$). All average item times in relation to item attributes are presented in Table 3.

	Item time average (min.sec)	P-value
Correctness		< .001
Correct	0.54	
Incorrect	1.34	
Presence of picture		< .001
Picture	1.14	
No picture	1.00	
Subject content		< .001
Developmental anatomy	0.34	
Gross anatomy	1.17	
Recency of content		.694
Review	1.03	
Current	1.03	

Table 3. *Item Outcomes and attributes: item time averages and significance*

Presence and patterns of change

A chi-square test of independence was conducted to test for significance between the presence of an answer change and the outcome of the selection and found significance (X^2 (1, N = 15,423) = 600.11, $p < 0.001$). Answer selections that were incorrect were more likely to have been changed compared to correct answer selections.

There was a significant relationship between the subject content of the item and the presence of an answer change, as determined by a chi-square test of independence (X^2 (1, N = 15,423) = 756.086, $p < 0.001$). There were nearly two times the amount of answer changes on GA items compared to DA items. On DA items, 63% of responses had not been changed. Furthermore, a significant relationship was identified between the subject content of the item and the pattern of change (X^2 (5, N = 15,423) = 118.324, $p < 0.001$). There were nearly twice as many correct to incorrect, multiple changes ending with a correct response, and multiple changes ending with an incorrect response on GA items compared to DA items.

Chi-square tests of independence found no statistical significance between the presence of a picture and the recency of the item content in relation to the presence or pattern of an answer change.

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Discussion

Research conducted on the topic of changing one's answer has consistently shown that it is largely beneficial to do so (Archer & Pippert, 1962; Coffey et al., 2024; McMorris et al., 1987; Ouyang et al., 2019; Pagni et al., 2017). The results of this study contradict these findings.

Breaking down this medical student sample into performance quartiles allowed for a deeper understanding of the impact of answer changing on outcomes. The highest performing students changed their answer less overall than any other performance quartile. When students did make an answer change, it was most commonly beneficial to high performing students. This finding differs from much of the existing literature on the impact of student proficiency (Archer & Pippert, 1962; Matthews, 1929; Merry et al., 2021), but supports more recent findings in health professional student populations (Miller et al., 2023; Ouyang et al., 2019), that changing answers is a more beneficial practice for high performing students.

Although many studies have observed the impact of binary answer changes (correct to incorrect, incorrect to correct, incorrect to incorrect), few studies had further examined the impact of multiple answer changes to a single item (Coffey et al., 2024; Ouyang et al., 2019). Because this study sorted individual item answer changes into single and multiple patterns, it was possible to establish that Q1 students were the most common performance quartile to make a single change from incorrect to correct. Adversely, Q4 students were nearly two times as likely than all other performance quartiles to change their answer multiple times and end with an incorrect selection.

The number of times a change was made, single or multiple, and the outcome of those changes may provide valuable insight into the differences in answering behaviors between these student samples. These findings suggest that higher-performing students might be more confident in their decision-making process, resulting in an educated, single change, while lower performing students could struggle with higher levels of self-doubt invoked by a lack of knowledge or confidence. Students that doubt their knowledge or feel unconfident would likely be more prone to guess an answer and change their guess multiple times, as confidence is a theme that has emerged in previous answer changing research (Cox-Davenport et al., 2014; Stylianou-Georgiou & Papanastasiou, 2017). Encouraging students to 'revisit and rethink' their answers if they feel unsure might be beneficial to high performing students, but for those who are lower performing, it could be harmful. Literature has shown that advice from faculty does have an impact on students' answer changing practices during exams, further highlighting the importance of how educators are addressing and advising their students as a whole (Bauer et al., 2007; Cox-Davenport et al., 2014; Merry et al., 2021).

This study also considered the relationship between time spent on an item and the presence and pattern of change as well as the outcome of those changes. When analyzing all responses together, a statistically significant relationship was found between time spent on an item and the presence of an answer change, with more time significantly related to the presence of a change. Additionally, it was found that longer item times were more commonly associated with incorrect answer selections. This suggests that the longer students spend on an item, the more likely they will be to change their answer and get the answer incorrect, as has also been found in previous research (Ouyang et al., 2019).

Given the significant relationships for the entire study sample regarding time and outcomes, the findings were not as expected when studying the same relationship with individual performance quartiles. The data showed that Q1 and Q2 students averaged the highest exam and individual item time averages but were the least likely to change their answer. In contrast, Q4 students averaged the lowest exam times, lowest average time spent on individual items and were the most likely group to change their answer. These findings showcase how different the answer changing behaviors were for the various performance quartiles, and how studying the sample as a whole led to results that did not represent the practices of the highest and lowest performing student groups. The difference in these findings might suggest that the highest performing students are much more intentional in their decisions and have higher metacognitive ability (Stylianou-Georgiou & Papanastasiou, 2017). By averaging higher times and lower numbers of answer changes, their choices seem to be more confident when compared to the behaviors of the lowest performing students. This, again, leads to the assumption that encouragement to either change or not change answers would likely not be beneficial to all students in a classroom.

Multiple previous studies found that item format showed significance in relation to answer-changing practices, but few other studies had considered other item attributes, such as the inclusion of a picture and specific content covered (Fischer et al., 2005; Geiger, 1997; Harvill & Davis, 1997). The results of this study suggest that not only is there significance between item attributes and answer changing, but that there are differences in the impact each specific item attribute can have on the presence and pattern of answer changes.

When considering the impact of the item content on time, there was a significant difference in the time spent on GA items compared to DA items, with GA items taking 43 seconds longer, on average, to be answered. Furthermore, answer selections on GA items were changed nearly twice as often as DA items. Although the presence of change was higher on GA items, the data showed that the most frequent pattern of change was from incorrect to correct. When students changed their answer on developmental items, the most frequent pattern of change was from correct to incorrect. Keeping an initial answer selection was most beneficial on DA items when comparing the two content subjects.

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The use of more time and the outcomes associated with GA items might be explained by the fact that the DA content within this course was self-study using only online materials. GA item content was pulled from introductory and clinical lectures, readings, and self-study modules. Although item difficulty was not formally recorded, both content subjects consisted of a mix of first and second order items. Knowing that content for DA items was only coming from one specific resource, students might have been able to better understand what was expected of them, which could have resulted in a lower average item time and less answer changing and/or doubting themselves compared to GA content. There is further research needed on the impact of subject, source material, and item difficulty on answer changing and time.

Limitations

A limitation to this study is that data from only one block exam was analyzed within this first-year medical school student sample. By analyzing data from only one exam, researchers were not able to determine if these outcomes were consistent and standard for this sample across all course exams throughout the semester. Another factor not under consideration was the order of the items within the randomized exams each student received. Because the exam time was capped at 180 minutes, or three hours, the time limit could have affected the presence or lack of a change on an item, especially for the items towards the end of the exam for each specific student. An additional limitation is that the performance quartiles students were assigned to were solely founded upon their performance on the third block exam and not the entire course.

Future Directions

Further research is needed to better understand the impact of specific item attributes on the answering behaviors of first-year medical students. Avenues for future research would be to follow a cohort of first-year medical students throughout an entire course to better understand if their answer changing behaviors are consistent, and likewise, their performance on the exams. Observing the answering behaviors of students within different performance quartiles over time would allow for a more solid understanding of their actions; in turn, this would allow for better supported suggestions to students, especially those who typically perform lower.

Furthermore, because of the differences this study noted in answer changing practices between GA and DA items, future research would likely benefit from breaking down the subject content further into specific anatomical content areas (e.g., leg, thigh, pelvic blood supply, etc.) for all anatomical regions. Some content regions might be more difficult or sensitive for students, and this could influence both their comprehension of the content, their decision to change their answer, and/or the time they spend on an item. Given the results, it would also be beneficial for researchers to observe whether items are first or second order for analysis. Researching the more in-depth item attributes could build upon the findings of this study and provide a stronger understanding of how the item content influences the presence and pattern of answer changing for students at various performance levels.

Additionally, it would be beneficial to measure students' confidence in their answer selections. By determining the confidence of students' initial answer selections and the answer changes they make, researchers would be able to better determine if answer selections and their associated outcomes result from guessing and/or luck or a true understanding and comprehension of the material. This is especially important when considering the differences between students in various performance quartiles.

Conclusion

Educators should hesitate before giving blanket, 'one-size-fits-all' recommendations on answering practices to their students and classrooms, as it could be harmful to specific students. The results of this study support the idea that students who perform at different levels might need to take different approaches to taking an exam and changing answers. In contrast to existing literature, this study showed that those who kept their initial answer selection were the highest performing students and those who logged the most-answer changes performed the lowest. Furthermore, high performing students were most likely to log a single answer change from incorrect to correct, with all other student populations showing a strong tendency to change their answer multiple times and end in an incorrect selection. Based on this study's findings, whether the advice for students is to 'stick with their gut' or 'revisit and rethink,' these claims will likely not be beneficial to all students in the classroom.

The time spent on items that resulted in an incorrect selection were, on average, 30 seconds higher than those that ended with a correct selection. For students, these findings can better guide their answering behaviors in terms of how long they allow themselves to stay on or revisit an item. The pattern of change that took students the longest amount of time was multiple changes ending in a correct response, but the next two longest average pattern times were a single change from correct to incorrect and a single change from incorrect to incorrect. This leads to the conclusion that allowing yourself to rethink and/or revisit an item for long periods of time is not always a beneficial answering behavior and has the potential to lead to negative outcomes. As a result of this study, it seems that advice early in the semester to develop sound metacognitive approaches and build confidence with the material would be more valuable than any exam day advice on answer changing.

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About the Authors

Marli Crabtree, MS, is a Clinical Anatomy PhD student at the University of Mississippi Medical Center. She has an MS degree in Anatomy Education from Johns Hopkins School of Medicine. Kenneth L. Thompson, PhD, is an Assistant Professor at the University of Mississippi Medical Center. He teaches statistics and research methodology. Additionally, he serves as the Director of Institutional Research in the Office of the Associate Vice Chancellor for Academic Affairs. Ellen M. Robertson, PhD, OTR/L, is an Assistant Professor in the Department of Physician Assistant Studies at Randolph-Macon College. She teaches gross anatomy, neuroanatomy, and research methods.

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Furthering the Understanding of Tumescent Fluids in Cadaveric Dissections

Melissa S. Zolnierz, PhD[1], George Kalu, MS[1], Morgan McBride, MS[2], Keanna Theobalt, MS[1], Miles Turk[1]

[1]Department of Pathology and Anatomical Sciences, Kansas City University, 2901 St. John's Blvd., Joplin, MO, USA

[2]Department of Pathology and Anatomical Sciences, Kansas City University, 1750 Independence Ave, Kansas City, MO, USA

Corresponding author: mzolnierz@kansascity.edu

Abstract

Surgeons and anesthesiologists use tumescent fluid to aid in the effectiveness of procedures. Injecting fluid to aid novice dissectors in improving speed, ease, and ability to distinguish planes has recently been proposed in the literature. In our study, we quantified dissections performed by first-year medical students after injecting fluid into the hands, feet, and faces. Photos of all aspects of the left (non-injected) and right (injected) sides were taken a week after dissection. Members of the study then individually scored the images based on what structures were dissected, their quality, and their dryness. Although previous studies found students felt the dissections were more manageable with fluid injections, no significant results occurred between the right and left sides of our three focus areas in quality or amount dissected. Injecting fluid in the hands, feet, and faces may not directly increase dissections' effectiveness; however, it can help prolong the longevity of dissections by reducing dryness. https://doi.org/10.21692/haps.2024.010

Key words: cadaveric dissection, tumescent fluid, dissection success, cadaveric drying, gross anatomy lab

Introduction

Surgeons and anesthesiologists use tumescent fluid to aid in the effectiveness of procedures (e.g., Fouche et al., 2022; Hudson 2020; Mahmoud & Elbahat, 2022). For instance, during liposuction, the tumescent fluid helps release adipose tissue from surrounding areas to make removal more successful. Further, the tumescent fluid provides anesthesia to the surgical area and helps reduce bleeding (Van Wicklin, 2022). Injecting fluid to aid novice dissectors in improving speed, ease, and ability to distinguish planes has recently been proposed in the literature (Hines et al., 2022; Loomis et al., 2022). However, these studies focus on qualitative results rather than quantitative ones. In our study, we quantified dissections performed by first-year medical students after injecting wetting solution into the hands, feet, and faces. These locations were chosen based on difficulty in dissecting due to the intricate nature of the structures and to reflect the areas Hines et al. (2022) and Loomis et al. (2022) highlighted in their study (hands and feet). Another note on the Loomis et al. (2022) study was that their research included a trained surgeon who knew the fascial planes of the hand. By understanding and utilizing fascial planes, which naturally occur to compartmentalize the body, one focuses the fluid to open a compartment to reveal localized structures or separate skin from underlying structures in a specific area (Kalbfell et al., 2016; Nikkhah et al., 2016). Most students and often instructors in the gross anatomy lab do not know this information or cannot interact with planes effectively like a surgeon to open specific dissection pockets. Further, gross dissections open the entire area, and often labs are not long enough to focus on precise locations and structures to complete a dissection based on compartments. Therefore, this study approached the injections from a non-plane point of view to replicate how a typical student could use tumescent fluid during dissection, injecting it in general areas rather than specific fascial compartments to help assist with the overall dissection.

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Materials and Methods

This study utilized formalin-embalmed donors dissected by first-year medical students as part of their anatomy curriculum (Hands n = 26 donors, Feet n = 28 donors, Face n = 29 donors) from the Joplin and Kansas City campuses of Kansas City University. Injections were done on the donor's right side, allowing the left to serve as a control. If donors had consistency issues between their left and right sides or anomalous features that impacted structure identification (e.g., a vessel branching from a non-standard location or a muscle with an extra tendon), they were excluded from the study. All other donors that were part of the dissection curriculum were utilized. This project was approved by the IBC board of Kansas City University, and all dissection materials were handled following institutional guidelines.

Twenty minutes before prescribed donor hand, foot, or face dissections, which began with skinning of the area, 30 ml of a facility-made wetting solution (water, ethylene glycol, 2-Phenoxyethanol, and Downey™) was injected by researchers at prearranged locations on the right side of the donor using a meat injector (plastic syringe with stainless steel metal injector, Amazon.com). This amount of wetting solution was selected because the volume was mentioned in Loomis et al., (2022) and what filled the injector. The timing ensured that students were not present in the lab to see the injections to bias the study potentially. The location of the injection points allowed for the spread of fluid throughout the area of the hand, foot, or face that was to be dissected during the day's lab. Unlike previous studies, planes were not followed as first-year medical students are not trained in planes before dissection.

More specifically, the hand and foot injections were made by inserting the needle under the skin in the proximal aspect of the wrist or ankle with the injector point radiating towards the medial, central, and lateral aspects of the hand (digits). The injector was inserted as far as possible, and fluid was released as the needle was slowly removed. For the face, injections were introduced under the skin near the ear and pointed toward the cheek's superior, middle, and inferior aspects. Because of the sturdiness of the syringe, no other incisions or equipment were needed for the injections.

First-year medical students followed Grant's Dissector (Detton, 2021) to dissect their donor's hands, feet, or faces. Faculty and other instructors assisted students when they had questions, but ultimately, students self-directed their dissections based on the dissector. Students chose whether a side was dissected superficially or deeply without the direction of the researchers. Typically, this decision was made based on which side had the better superficial structures. The better side remained superficial, while the other side was taken to a deeper layer. Students were reminded to spray their dissections while they worked and when they were finished for the day to keep the area hydrated. This maintenance included spraying and wrapping the area with a towel dampened with the wetting solution. No further injections were made once the students began the dissection.

To allow multiple locations and researchers from these locations to examine and score the same donors and structures, photos were taken using a cell phone camera of all aspects of the left and right sides of the hands, feet, or faces a week following the initial dissection. Scores were taken from these images. Although photos add a confounding variable and limit 3D views, photos ensured everyone saw the same structures regardless of location. This week gap provided students time to finish the dissection, find the required structures, and clean them to get better visualization. This period allowed drying to occur, another aspect analyzed in this study. Dryness can impact a structure's appearance, influencing what a student sees during learning and the gross anatomy practical exam.

Scores were based on a structure's appearance and how a student would perceive the structure during learning and examination, the end goal of the dissection process. This study included multiple perspectives on each dissection because of the variability in how someone perceives a structure, especially in a photograph. Members of the study (n = 5) individually scored the images based on what structures were dissected following the students' testable structure list, their quality, and their dryness (Table 1). The researchers included a faculty member and four clinical anatomy fellows, all well-versed in these dissections and structures. In sum, 15 structures, which included muscles, nerves, and vessels, were scored in the hand, 14 in the foot, and 14 in the face. All structures were given a two-part score reflecting if they were dissected and how well and a dryness score. Since the goal of the dissection was to find and preserve the structure, the overall dissection was given a positive-based score. Dryness, which negatively impacts the structure within the learning environment, was given a negative score as it takes away from preservation. Table 2 provides an excerpt on the scoring of selected hand structures from one donor. For instance, in the hand when scoring the oblique head of the adductor pollicis muscle, if the muscle could fully be seen (origin, insertion, muscle belly) and intact (muscle fascicles still together), the dissection score would be recorded as 5. If no part of it showed dryness, it would be given a 0 for the dryness score. When these scores (dissection and dryness) are combined, a total score of 5 is given for the structure, the best score a structure could receive. However, if the muscle was fully dissected (score of 5) but had started to dry out at the edges, the dryness score would be -3, giving an overall score of 2. This score reflects the muscle not being the best example making learning the structure and its interactions more difficult.

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Dissection Score Basis	Score
The structure is visible and fully dissected	5
The structure is visible but only partially dissected (full structure not visible because of fascia or other material or minor damage)	3
The structure is visible but destroyed for identification purposes (muscle belly shredded or cut in a way that does not visually connect or key structure points no longer visible)	1
The structure is not visible/ not dissected	0
Dryness Score Basis	
The structure is fully hydrated	0
The structure is starting to brown/ dry	-3
The structure is completely dried out	-5

Table 1. *Grading criteria used to score structures within the hand, foot, and face. Each structure had a dissection (positive) and dryness (negative) score accessed.*

Structure examined	*Observer 1*		*Observer 2*		*Observer 3*		*Observer 4*		*Observer 5*	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**
Abductor pollicis brevis muscle (dissection)	5	3	5	3	5	5	5	5	5	3
Abductor pollicis brevis muscle (dryness)	0	0	0	0	0	0	0	0	0	0
Flexor pollicis brevis superficial head muscle (dissection)	5	1	5	3	5	5	5	5	5	3
Flexor pollicis brevis superficial head muscle (dryness)	0	0	0	0	0	0	0	0	0	0
Oblique head adductor pollicis muscle (dissection)	5	0	5	0	5	5	5	5	5	0
Oblique head adductor pollicis muscle (dryness)	0	0	0	0	0	0	0	0	0	0
Transverse head adductor pollicis muscle (dissection)	5	0	5	0	5	3	5	3	5	0
Transverse head adductor pollicis muscle (dryness)	0	0	0	0	0	0	0	0	0	0
Abductor digiti minimi muscle (dissection)	5	1	5	3	5	5	5	5	5	5
Abductor digiti minimi muscle (dryness)	0	0	0	0	0	-3	0	0	0	0
Total dissection score	25	5	25	9	25	23	25	23	25	11
Total dryness score	0	0	0	0	0	-3	0	0	0	0
Total all scores	**25**	**5**	**25**	**9**	**25**	**20**	**25**	**23**	**25**	**11**

Table 2. *Select sample data of how five structures, out of the 15 examined, were scored by the researchers on one donor's hands. The 'R' refers to the right treated side while the 'L' refers to the scores for the left control side. The bottom rows show how this data would be combined for analysis. The total dissection score is the combined dissection score assessed for all parts of the hand. The total dryness score is the combined dryness score assessed for all parts of the hand. The total all scores is the sum of the total dissection score and total dryness score for all parts of the hand.*

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Researchers based how they scored the structures on two things. First, how would a first-year medical student perceive the structure when looking at the image? The dissection's structures, reference structures, dryness, and completeness were considered. Second, given that students are assessed on their dissection via their ability to identify a structure on an examination, scoring a structure lasted no more than a minute to reflect how long students were given to identify structures during the practical exam. For example, a structure was marked absent if researchers could not locate the entire, complete structure in the photos during this time frame. These scores were combined for each individual's hand, foot, and face to reflect the overall dissection (Table 3). The overall values were compared statistically between the left and right sides using Wilcoxon signed-ranks Tests in SPSS (version 29, IBM). Factors examined included total structures dissected (number of items from the structure list dissected on that particular hand, foot, or face), instances of dryness (number of structures exhibiting dryness), dryness score (average of dryness seen for the entire area), total dissection score (average completeness of the dissection), and total dissection score with dryness factored in. The last factor provided an understanding of the longevity of the structures dissected.

		Donor 1		*Donor 2*		*Donor 3*		*Donor 4*		*Donor 5*	
		R	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**
Observer 1	Number dissection score	14	7	12	8	5	7	6	12	6	9
	Number dryness score	0	0	0	0	0	0	0	0	0	0
	Total dissection score	*46*	*19*	*48*	*16*	*17*	*27*	*30*	*52*	*22*	*31*
	Total dryness score	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total all scores	**46**	**19**	**48**	**16**	**17**	**27**	**30**	**52**	**22**	**31**
Observer 2	Number dissection score	12	7	10	9	3	9	6	14	6	4
	Number dryness score	0	0	0	0	0	0	0	0	0	0
	Total dissection score	*50*	*19*	*40*	*25*	*9*	*21*	*30*	*60*	*20*	*14*
	Total dryness score	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Total all scores	**50**	**19**	**40**	**25**	**9**	**21**	**30**	**60**	**20**	**14**
Observer 3	Number dissection score	16	11	14	10	3	11	8	15	7	9
	Number dryness score	0	0	0	2	0	0	6	0	0	0
	Total dissection score	*54*	*47*	*62*	*46*	*9*	*33*	*40*	*67*	*27*	*27*
	Total dryness score	*0*	*0*	*0*	*-6*	*0*	*0*	*-18*	*0*	*0*	*0*
	Total all scores	**54**	**47**	**62**	**40**	**9**	**33**	**22**	**67**	**27**	**27**
Observer 4	Number dissection score	8	12	11	9	5	7	8	14	11	7
	Number dryness score	0	3	0	1	0	0	0	0	0	0
	Total dissection score	*38*	*38*	*49*	*29*	*19*	*23*	*38*	*62*	*43*	*29*
	Total dryness score	*0*	*-9*	*0*	*-3*	*0*	*0*	*0*	*0*	*0*	*0*
	Total all scores	**38**	**29**	**49**	**26**	**19**	**23**	**38**	**67**	**43**	**29**
Observer 5	Number dissection score	15	12	12	11	4	11	8	13	7	8
	Number dryness score	0	0	0	0	0	0	2	0	0	0
	Total dissection score	*51*	*46*	*56*	*47*	*14*	*33*	*38*	*63*	*25*	*24*
	Total dryness score	*0*	*0*	*0*	*0*	*0*	*0*	*-6*	*0*	*0*	*0*
	Total all scores	**51**	**46**	**56**	**47**	**14**	**33**	**32**	**63**	**25**	**24**

Table 3. *Select sample data of how five donors, out of the 26 examined, hands were scored by each researcher. These numbers combine the information for all 15 structures scored within the hand. The 'R' refers to the right treated side while the 'L' refers to the scores for the left control side. The number dissection score is the total number of structures out of the possible 15 dissected. The number dryness score is the total number of structures out of the 15 exhibiting a stage of dryness. The total dissection score is the combined dissection score assessed for all parts of the hand. The total dryness score is the combined dryness score assessed for all parts of the hand. The total all scores is the sum of the total dissection score and total dryness score for all parts of the hand.*

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Results

Although previous studies found students felt the dissections were more manageable with fluid injections, no significant results occurred between the right and left sides of our three focus areas in total dissection score (with and without dryness factored in) or the number of structures dissected (Table 4). However, injections impacted the dryness of structures over time. The right foot and face were less dry than their counterparts a week after the initial dissection. This result was for both the overall dryness and specific structure dryness in the foot and the number of structures in the face (although total structures for the face was close to p-value ≤ .05). The interclass correlation coefficient for the average measures for the researchers for the hand was 0.927 (95% CI 0.889-0.954), 0.923 for the foot (95% CI 0.886-0.951), and 0.881 for the face (95% CI 0.825-0.923).

Discussion

From scoring the student dissections for dissection completeness and dryness, injecting tumescent fluid did not impact students' dissection performance as neither the side used for superficial or deep dissection nor the number of structures dissected differed significantly between the injected versus control sides. Injecting the tumescent fluid did not assist students in teasing out small or intricate structures or help improve the overall dissection process. This finding differs from what Hines et al. (2022) and Loomis et al. (2022) experienced during their studies. Differences in results may be due to having students dissect instead of a trained surgeon or being directed by one. Students in this dissection worked independently. While some separation may have occurred due to the presence of the tumescence fluid, it was not enough to directly impact what students saw or how they approached the dissection. As the injections were not discussed with students, they were not swayed or biased about the potential improvement of the dissection.

		Number of structures dissected	Number of dry structures	Total dissection score	Total dryness score	Total all scores
Hand	Z	-0.043	-0.700	-0.102	0.517	-0.254
	Asymp. Sig. (2-tailed)	0.966	0.484	0.9196	0.517	0.799
Foot	Z	-0.264	-3.235	-0.592	-3.113	-1.685
	Asymp. Sig. (2-tailed)	0.791	0.001	0.554	0.002	0.092
Face	Z	-0.502	-2.790	-0.616	-1.930	-0.144
	Asymp. Sig. (2-tailed)	0.616	0.005	0.538	0.054	0.885

Table 4. *Wilcoxon signed-rank test results for the three areas examined in the project based on comparing the right, treated part to the left, control part. Gray boxes indicated a p-value ≤ .05.*

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One may argue that the injections in this project did not utilize fascial planes like the original articles and, therefore, impacted the results. Although students have a basic understanding of the anatomy of the hand, foot, and face, they lack the hours of experience separating fascial planes and structures. Spending time discussing these planes and how to inject tumescent fluid properly into these planes for success is beyond the scope of the general gross anatomy lab. It does not fit into the limited time for dissections during the first-year medical school curriculum. Therefore, the results reflect a more common lab experience with limited time, equipment, and students acting independently during dissection.

Although injecting fluid in the hands, feet, and faces may not increase the effectiveness of student dissections, it can help in the longevity of areas students find challenging to dissect and learn. This finding is especially true for the feet and faces of the donors within this study, which showed reduced drying on the injected side. The hands did not show this result. This may be due to the hands being dissected first within the curriculum, several weeks before the feet were dissected and over a month before the faces, meaning the donors were less open to the environment and potential drying. In addition, since this dissection occurred earlier in the semester, students may have been more vigilant in spraying and wrapping their hands as they were in later dissections. In any case, by reducing dryness, the donors' structures are more likely to be identified during examination, and valuable donor resources for the students are preserved.

As Hines et al. (2022) and Loomis et al. (2022) concluded, tumescent fluid is a new method that should be integrated into anatomy dissection courses utilizing human cadavers. Students can perform injections during dissection (before removing skin) and reduce dryness in hard-to-dissect areas. By using meat injectors instead of medical-grade syringes, this method is an affordable supplement to help with the longevity of donors. Future studies can examine injections throughout the dissection process to see if they can help separate visible structures, though a smaller syringe may be required.

About the Authors

Melissa Zolnierz is an Assistant Professor of Anatomy at Kansas City University. Her research focus is on medical education. George Kalu is a medical student and Clinical Anatomy Fellow at Kansas City University, and other research interests include gynecology. Morgan McBride is a medical student and Clinical Anatomy Fellow at Kansas City University, and other research interests include neurology. Keanna Theobalt is a medical student and Clinical Anatomy Fellow at Kansas City University, and other research interests include sports medicine. Miles Turk is a medical student and Clinical Anatomy Fellow at Kansas City University, and other research interests include cardiology.

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Student Performance and Exam Quality in Student- Versus Instructor-Created Exams in Human Physiology

Laura S. Kabiri, PT, DPT, PhD[1], Catherine R. Barber, PhD[2], Thomas M. McCabe, PhD[2], and Augusto X. Rodriguez, PhD[1]

[1]Department of Kinesiology, Rice University, Houston, Texas, United States of America

[2]Center for Teaching Excellence, Rice University, Houston, Texas, United States of America

Corresponding author: laura.kabiri@rice.edu

Abstract

Multiple-choice questions (MCQs) are commonly used in undergraduate introductory science, technology, engineering, and mathematics (STEM) courses, and substantial evidence supports the use of student-created questions to promote learning. However, research on student-created MCQ exams as an assessment method is more limited, and no studies have investigated whether student-created exams address inequities in STEM outcomes. The current study explored student-created and instructor-created MCQ exams with students in an undergraduate human physiology course ($N = 46$). Descriptive statistics, Pearson correlations, and a paired samples t test compared student performance on the two versions. Multiple methods assessed exam quality, including the percentage of students who responded correctly to each question (difficulty), the corrected item-total correlation coefficient (discrimination), and an objective rater score (cognitive complexity). A series of four repeated measures factorial analyses of variance examined demographic subgroup performance differences. Students performed significantly better on student- rather than instructor-created exams. Both versions discriminated similarly and were moderately to strongly correlated with each other. However, student-created exams had a larger percentage of "easy" questions. Students who identified as first generation and/or low income performed significantly higher on student-created exams, but still failed to achieve the same level of performance as their peers. Student-created MCQ exams may serve an important role as part of a comprehensive assessment plan. https://doi.org/10.21692/haps.2024.011

Key words: assessment, engagement, undergraduate

Introduction

Student Performance and Exam Quality in Student- Versus Instructor-Created Exams in Human Physiology

Examinations that rely heavily on multiple-choice questions (MCQs) are commonly used in introductory science courses (Stanger-Hall, 2012). From the instructor perspective, MCQs offer ease and accuracy of grading, improved exam integrity through multiple test forms, and the ability to assess a wider range of course content (Simkin & Kuechler, 2005, pp. 75-76). For students, advantages of MCQs include the perception that MCQs are more objective and easier than constructed response (e.g., essay) tests and provide the opportunity to guess the correct response (Simkin & Kuechler, 2005). Because repeated quizzing with feedback reinforces learning (Marsh et al., 2007; Kulasegaram & Rangachari, 2018), MCQs can be particularly effective in the context of formative assessment. Furthermore, because the MCQ format is overwhelmingly used on high-stakes standardized tests (e.g., the Medical College Admission Test), MCQ exams provide STEM students with an opportunity to practice reading, understanding, and responding to this type of question in a relatively lower-stakes environment.

There is support for the use of MCQ exams in physiology education. For example, the Human Anatomy and Physiology Society's (HAPS) Anatomy and Physiology Comprehensive Exam is a standardized MCQ exam that assesses students' knowledge of content aligned with HAPS learning outcomes (Witt & the HAPS Testing Task Force, 2017). In addition, performance on MCQs is correlated with performance

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on long essay questions in physiology, with superior performance on MCQs (Pepple et al., 2010). In light of the large quantity of content covered in physiology courses, MCQs can also serve an important role in pre-tests of student knowledge, allowing instructors to pinpoint areas where students need more instruction (Goodman et al., 2018).

Despite these benefits, criticisms of MCQs abound, particularly regarding their potential bias within the context of standardized exams. Extensive research underpins guidelines for fair test construction, implementation, and interpretation (e.g., American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 2014; Dorans & Cook, 2016), including strategies for ensuring that MCQ tests are reliable and valid (Towns, 2014) as well as fair (McCoubrie, 2004). However, these guidelines do not always translate into classroom practice (Killam & Camargo-Plazas, 2022). For example, a common grading strategy in MCQ exams is to deduct points for incorrect answers to discourage students from guessing. However, such penalties can disadvantage female test-takers, who may be more risk-averse (Iriberri & Rey-Biel, 2021), more likely to skip difficult questions due to stereotype threat (Riener & Wagner, 2017), and less likely to self-assess as "successful" in STEM disciplines, thereby leading them to skip questions and forgo potential points for correct answers to avoid potential deductions for incorrect answers (Saygin & Atwater, 2021). Furthermore, sex differences in test anxiety may partially explain females' under-achievement on STEM exams, with the most pronounced achievement impacts seen in lower division courses that rely heavily on MCQ exams (Salehi et al., 2019). When performance on an MCQ exam is impacted by such factors as risk-taking, stereotype threat, self-efficacy, and anxiety, the associated test score is a biased measure of student learning.

As another example of bias, Sinharay and Johnson (2023) have pointed out that standardized tests using MCQs as the primary question format may rely on knowledge based on dominant cultural viewpoints or experiences, thereby failing to account for other frames of reference. Such an assessment approach neglects the goal of inclusivity, which Dewsbury and Brame (2019) define as "the practice of including people across differences … [and] recognizing and working to mitigate biases that lead to marginalization or exclusion of some people" (p. 1). Inclusive teaching techniques, such as providing student choice and engaging students as active participants in the learning and assessment process, positively impact students belonging to historically marginalized groups (Arif et al., 2021).

To facilitate inclusion, some instructors have sought strategies that empower students as co-creators in the learning process (Doyle & Buckley, 2022). Doyle and colleagues (2021) define co-creation as "students and instructors working together to establish learning environments where the responsibility for achieving learning outcomes is a shared endeavor" (p. 494). Co-creation as an instructional strategy falls within the constructivist learning paradigm, which asserts that people learn by actively engaging with their environments and by using the information gained through these interactions to refine their mental representations of reality (Doyle & Buckley, 2022). For example, to create instructional materials, students must take on the role of a teacher, which allows them to develop a deeper understanding of the course content while experiencing empowerment in their learning (Coppola & Pontrello, 2020). In the same way, generating questions about what they are learning is a cognitively complex skill that requires students to approach the subject matter from a new perspective (Aflalo, 2021).

Substantial evidence supports the use of student-created questions to promote learning. Much of the research in this area has been conducted using PeerWise, a free online platform that facilitates the generation and sharing of a student-created MCQ repository (Denny, 2024). Two systematic reviews have examined student-created MCQs in STEM educational settings. In their review of 17 papers on medical student-created MCQs, Toussi and colleagues (2022) generally found positive associations between writing MCQs and grades, though this finding was not universal, and the quality of student-created MCQs varied. Similarly, in a systematic review of eight articles on the use of PeerWise in physiology courses, Khashaba (2020) concluded that students are capable of creating good questions, though the level of cognitive complexity is often low. Consistent with Touissi et al.'s (2022) review, Khashaba found an inconsistent impact of writing MCQs on learning outcomes. Nonetheless, Khashaba (2020) suggested that a unique benefit of having students generate MCQs is the creation of a large body of MCQs for future exams. Touissi and colleagues (2022) concluded that additional research is necessary to clarify the pros and cons of this strategy and to better understand which populations it benefits.

Additional studies have examined student-created MCQs as a method of assessing student learning. However, once again the evidence on this approach is mixed. Bates and colleagues (2014) found that providing structured guidance resulted in high-quality student-created physics exam questions. Schullo-Feulner et al. (2014) observed that pharmacy student-created patient vignettes and MCQs were comparable to faculty-written exam items in terms of structure, content, and discriminability. Similarly, Shah and colleagues (2019) trained medical students to write MCQs for a midterm exam. The researchers found no significant difference between student- and instructor-written questions in terms of difficulty, and the student-written questions boasted a higher discrimination index.

However, these positive findings are somewhat tempered by research suggesting limits to the benefits of student-created exams. For example, Jobs and colleagues (2013) found that

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low-performing medical students performed significantly better on student-created MCQ exams compared to lecturer-created MCQ exams, whereas high-performing medical students showed no difference. Jobs et al. (2013) suggested that lower-performing students may have memorized the pool of student-created questions rather than developing a deeper understanding of the material. This supposition is supported by the findings of Papinczak et al. (2012), who also found that medical students performed better on student-generated questions that were previously seen in a question bank. In addition, the majority of students in Papinczak et al.'s (2012) study did not report enhanced metacognitive skills as a result of creating MCQs, and only a small percentage reported that the activity boosted their problem-solving ability and their learning.

Overall, the existing literature supports use of student-created question writing as a constructivist learning strategy. Research on student-created MCQ exams as an assessment method in undergraduate STEM courses is more limited, and no studies have explored whether student-created exams address inequities in STEM outcomes. In order to endorse student-created exams as equitable, evidence is needed that such exams are at least comparable to instructor-created exams in terms of quality and that performance on student-created exams is equivalent for underrepresented students and their non-underrepresented peers. The current study explores the use of student-created MCQ exams in an undergraduate human physiology course. The aims of the study were to compare student-created MCQ exams with instructor-created MCQ exams in terms of student performance and exam quality and to identify any demographic subgroup-level differences in performance on both student- and instructor-created exams.

Methods

Participants

In the fall of 2023, students enrolled in the three-hour undergraduate lecture course KINE 301: Human Physiology were invited to participate in this study. This project was approved by the Institutional Review Board at [blind] University, and informed consent was obtained from all participants. Students were informed about the research study during the initial class session by the instructor and through the syllabus. Students were informed that except for one voluntary demographic question, all assessment practices involved in the research study were part of usual course procedure. Participation was not tied to course performance or assessment, and students could decline participation at any time through written refusal to the provided email. Opportunities for discussion were provided and all questions answered.

Procedures

During the first week of class, students received instructions on writing exam questions. The instructor provided a handout with best practices and reviewed the information with students. Students then created a Google form for the course to which they added individually written exam questions throughout the semester. The instructor had access as an editor to allow question importation into a mass database for each chapter. In small groups, students practiced creating a multiple-choice question with four answer choices and included an answer key with a citation from course materials.

After each student reviewed their own questions for appropriate grammar, punctuation, and completeness, small group peer review served as a second quality control measure. While grammar-checking software was allowed and encouraged (e.g., Grammarly, document editing options), no other internet or artificial intelligence software was allowed for content creation. Requiring citations in the answer key (e.g., video name and time stamp from recorded lecture or textbook page number) also helped ensure content was unique to the course and student-generated. Each student wrote two or three multiple-choice questions on subtopics divided among the groups to create a comprehensive test bank for each topic within the course. This general practice occurred throughout the semester during the last 10-20 minutes of each class session, resulting in student-created questions for each chapter of course content. A rigorous student-monitored and enforced honor code exists on campus and was utilized to discourage students from sharing test questions with other students outside of class.

The instructor imported individual student questions into a single test bank by content (e.g. text chapter or major concept). Student-generated questions were imported randomly for each bank, allowing anonymity and random item number assignment for each question within each student-created test bank. Instructor-created questions within the instructor-created test bank included questions from the test bank provided by the textbook, reviewed or modified by the instructor, or written by the instructor. A random number sequencer facilitated selection of questions from each bank. Other than minor grammar, punctuation, or formatting changes, no edits to student-created or instructor-created questions were made. Inclusion criteria included a complete multiple-choice question with four answer choices and an answer key. Questions were excluded if they assessed a topic already included on the exam, were non-applicable to course content (e.g., material not covered in class from the textbook test bank), or were the wrong format (e.g. true/false, fill-in-the-blank, essay).

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Data Collection

Prior to this research study, assessment for this course utilized four non-comprehensive exams of 50 questions each for a total of 200 questions total. To maintain the overall question total and testing burden, two versions of each exam, student-created and instructor-created, were generated with 25 questions each. An equal number of questions from each topical test bank (student and instructor) were included on each version to standardize the percentage of material from each chapter or topic. A coin flip determined if version A or B was student-created for each of the four exams, and students had the option to take either version first to minimize the effect of testing fatigue. Students were blinded to version assignment prior to testing. To encourage equal effort on both versions, grades were hidden upon submission, and students retained the higher score of the two versions. For each exam, students were made aware of the exam version author after exam scores were calculated and released.

One optional unscored (0 point) demographic question at the beginning of Version A was included once during the semester to identify known underrepresented or underperforming groups in STEM. Students self-selected any demographic subgroups with which they identified, including first generation students (first in their family to attend college), low income college students, racial/ethnic/cultural minorities, female/feminine/woman, or none of the above. Students were allowed to select more than one subgroup if applicable.

Statistical Analysis

All statistical tests were run using SPSS (version 29, Chicago, IL, USA), with an alpha value of ≤ 0.05 to indicate significance. Demographics for the sample were calculated using frequencies and percentages. For each participant, exam performance was calculated as the participant's average score across all four exams for each authored version; thus, each participant had two exam performance scores: student-created and instructor-created. Exam performance was assessed with descriptive statistics, including mean, standard deviation, minimum, and maximum. Additional descriptive statistics included completion time mean and standard deviation, percentage of students who performed higher on each version, and percentage of students who failed each version (<70% credit earned). A paired samples *t* test was used to compare exam mean scores between versions for the sample as a whole. The sample mean for each exam version and Pearson correlations between versions were also analyzed for each exam (1-4).

Exam quality was assessed by comparing student-generated questions to those created by the instructor. Multiple methods assessed question quality, including the percentage of students who responded correctly to each question as an estimate of item difficulty, the corrected item-total correlation coefficient as an estimate of discrimination, and an objective rater score of cognitive complexity. Consistent with existing suggested standards for item difficulty, questions were classified as "easy" if greater than 85% of the group answered it correctly, "medium" if between 30-85% of the group answered correctly, and "hard" if less than 30% answered correctly (*New Quizzes Quiz and Item Analysis*, 2023). The corrected item-total correlation coefficient (ITCC) [range: -1, 1] indicates the correlation of an individual question with the overall exam score while excluding that item and serves to assess question discrimination. ITCC values were further categorized into "unexpected relationship" (negative value), "no relationship" (value of 0.0), "poor relationship" (<.2), and "good relationship" (value of 0.2-1.0) (*New Quizzes Quiz and Item Analysis*, 2023). Note that in this context, higher values indicate greater discrimination, which is considered a desirable quality of an exam question (Towns, 2014). Finally, the objective rater scores involved blind coding of each question as requiring lower-order cognition (e.g., recall) or higher-order cognition (e.g., evaluation) (Cleveland et al., 2018; Crowe et al., 2008). Two of the authors who were not involved in data collection independently coded each question, blind to exam format (student- vs. instructor-created), with final codes established by consensus. This process resulted in a percentage of lower- and higher-order questions for each exam, which allowed comparison of the cognitive complexity of student- and instructor-created questions. Chi-square tests compared categorical-level data.

A series of four repeated measures factorial analyses of variance (ANOVAs) explored potential subgroup differences. Each ANOVA explored the interaction of exam version (student-created vs. instructor-created) and student self-identification (yes vs. no) with one of the demographic variables: first generation, low income, racial/ethnic/cultural minority, and female/feminine/woman. In addition, the main effect of each demographic variable was examined. Descriptive statistics, including means and standard deviations by version and demographic subgroup as well as effect size (partial eta-squared, η^2) for each *F* test, were also calculated.

Results

In all, 46 of 46 students enrolled in KINE 301: Human Physiology agreed to participate in this study for a participation rate of 100%. Each student completed a total of 4 exams during the semester using the method described above. One student did not complete Exam 1 and one student did not complete Exam 3 creating a sample of 45 for exam-level analyses and a sample of 44 for paired *t* tests and demographic subgroup analyses. Each exam consisted of 25 student-created and 25 instructor-created questions for a total of 200 questions for comparison. The majority of the sample identified as female, and almost half as a racial, ethnic, or cultural minority. Detailed demographics of the sample may be found in Table 1.

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Identity	Frequency	Percentage
First Generation College Student	11	24%
Low Income College Student	13	28%
Racial, Ethnic, or Cultural Minority	21	46%
Female/Feminine/Woman	31	67%

Table 1. *Demographic identities of the sample (n = 46).*

Overall Student Performance

Aggregate exam performance across all four exams indicated that an average of 83% of students performed higher on student-created exams in slightly less time (12.59 minutes). Additional aggregate exam descriptive statistics may be found in Table 2. Paired samples *t* tests revealed a significant difference in aggregate mean exam score between student- ($M = 86.88$, $SD = 9.82$) versus instructor-created ($M = 73.65$, $SD = 11.87$) exams ($t(43) = -13.70$, $p < 0.001$) with a large effect size ($d = -2.07$). Means and standard deviations of student- and instructor-created exam scores, as well as correlations between the two exam versions, at each of the four exam time points can be seen in Figure 1. The pattern of means over time suggests that the difference in performance on student- and instructor-created exams was modest on Exam 1 and more pronounced on Exams 2-4. In addition, the correlations between exam versions ranged from 0.43 (Exam 4) to 0.73 (Exam 3), suggesting that performance on student-created exams moderately to strongly predicted performance on instructor-created exams.

Statistical Measure	Student-Created	Instructor-Created
Mean Score (± SD)	86.75 (± 1.258)	73.50 (± 5.066)
Minimum Score	24	24
Maximum Score	100	100
Mean Completion Time (± SD)	12.59 minutes (± 2.12)	13.92 minutes (± 2.34)
Mean Percentage of Students Who Performed Better on This Version (± SD)	83% (± 19.987)	17% (± 19.987)
Mean Percentage of Students Who Failed (< 70%) This Version (± SD)	4% (± 1.258)	16% (± 6.800)

Table 2. *Aggregate exam performance statistics by exam creator for all four exams (n = 46).*

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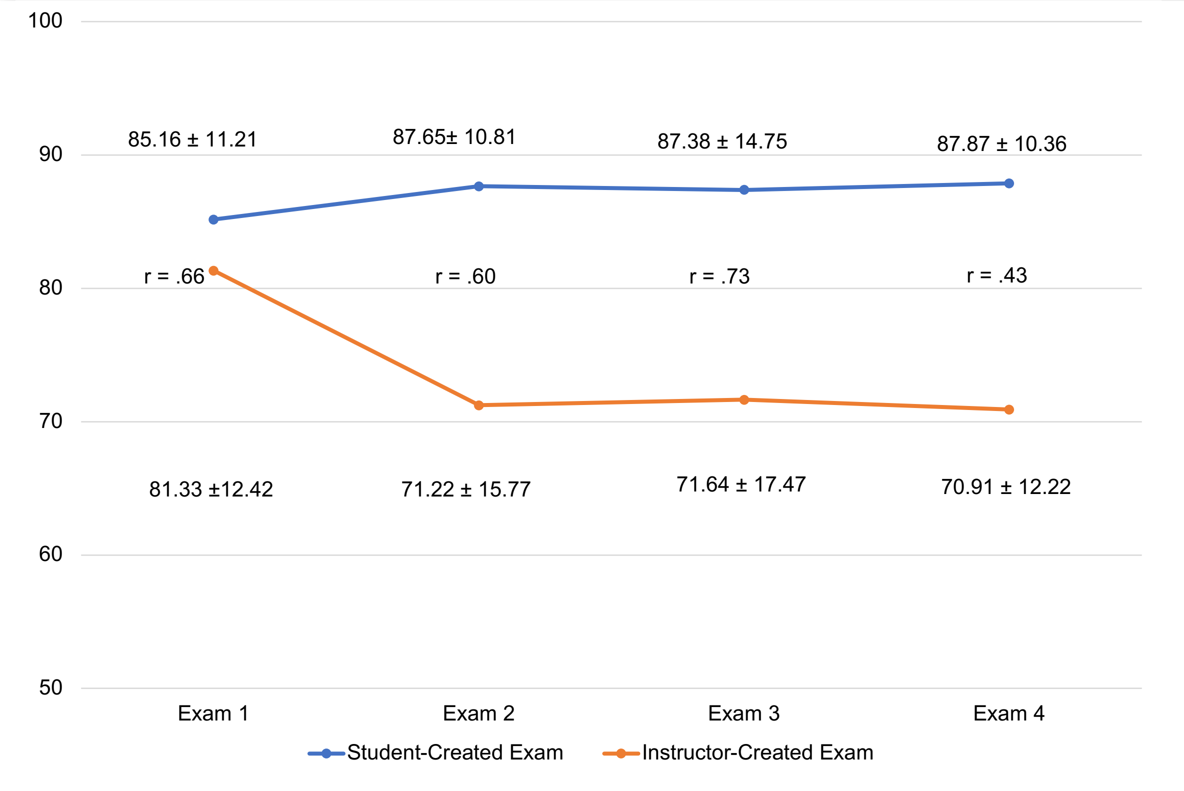

Figure 1. *Mean score trends and correlations by exam and creator.*

Exam Quality

To assess exam quality, difficulty was compared graphically between student- and instructor-created questions, as seen in Figure 2. The percentage of students who answered a question correctly (an estimate of difficulty) was plotted for each question, with student and instructor questions plotted separately. The distribution of difficulty estimates indicates that students wrote more questions that were "easy" (n = 66) and slightly fewer questions that were "hard" (n = 0) compared to the instructor (n = 35; n = 4). Within the "medium" range of difficulty, a larger percentage of students answered student-created questions correctly.

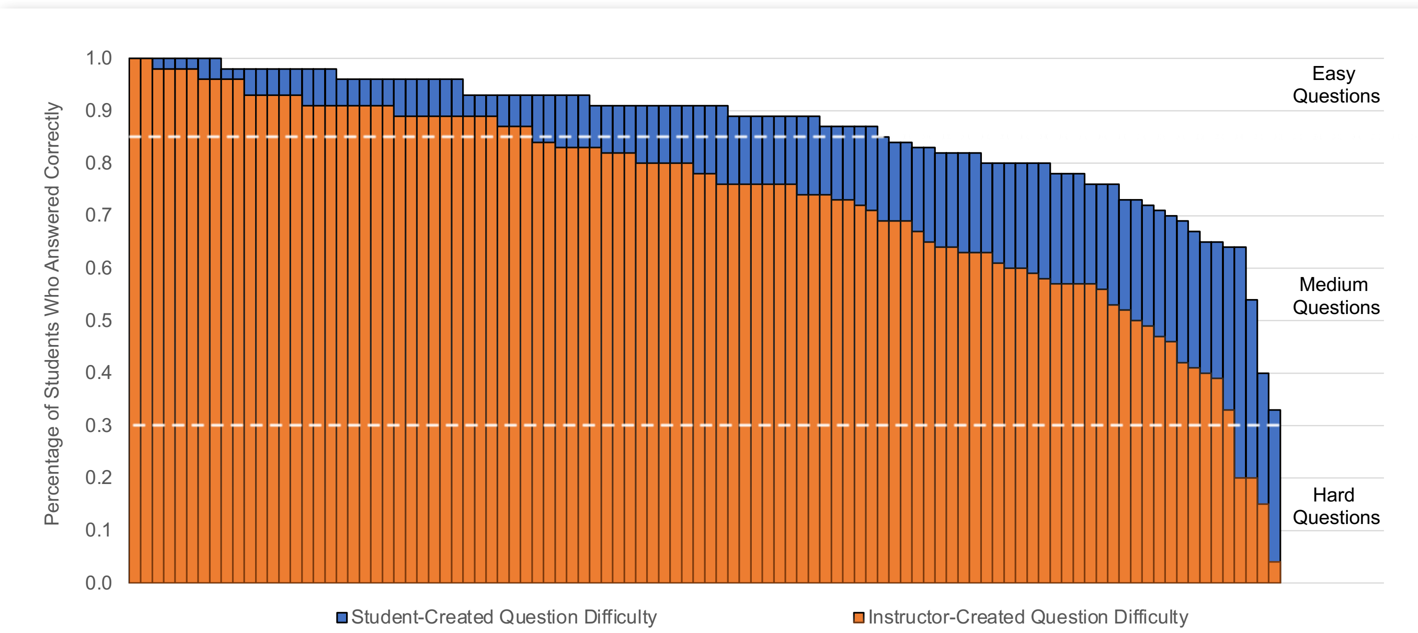

Figure 2. *Percentage of students who answered each of 100 questions correctly by creator and difficulty category.*

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There was no difference between student- and instructor-created exam question discrimination in terms of ITCC categories, as indicated by a chi-square test that revealed no significant association: X^2 (3, N = 200) = 6.15, p = 0.104. Question classification by exam version and ITCC category can be found in Table 3. Average discrimination scores for both exam versions were in the "good" range (student-created: M = 0.25, SD = 0.20; instructor-created: M = 0.33, SD = 0.23). Furthermore, the coders identified 14% of instructor-created exam questions and 6% of student-created exam questions as requiring higher-order cognition; however, this difference slightly exceeded the threshold for statistical significance: X^2 (1, N = 200) = 3.56, p = 0.06.

Question Creator	Unexpected Relationship	No Relationship	Poor Relationship	Good Relationship	Total
Peer	5	9	22	64	100
Instructor	10	2	22	66	100
Total	15	11	44	130	200

Table 3. *Corrected item-total correlation coefficient categorical question classification by creator.*

Demographic Subgroup Performance

The results of the paired t test comparing student- and instructor-created versions indicated an overall main effect of version favoring student-created exams. However, as noted previously, equitable tests should elicit comparable performance by students from various demographic subgroups. Thus, a series of ANOVAs explored the interaction of exam version (student or instructor) and each demographic subgroup, as well as the main effect of each demographic subgroup. Means and standard deviations by exam version (student or instructor) and demographic subgroup can be seen in Table 4. There were no violations of Mauchly's test. Within each ANOVA, there was no significant interaction between exam version and demographic subgroup. This indicated that the pattern of performance favoring student-created exams was consistent across all subgroups.

	Demographic Subgroup							
	First Generation		*Low Income*		*Racial/ethnic/cultural Minority*		*Female*	
Exam Version	Yes (n=11)	No (n=33)	Yes (n=12)	No (n=32)	Yes (n=20)	No (n=24)	Yes (n=30)	No (n=14)
Student	78.59 (10.13)	89.64 (8.13)	77.96 (10.91)	90.22 (7.02)	84.98 (9.21)	88.46 (10.22)	86.63 (9.48)	87.39 (10.86)
Instructor	63.50 (9.72)	77.03 (10.61)	62.92 (10.86)	77.67 (9.61)	70.15 (11.13)	76.56 (11.90)	72.52 (11.57)	76.07 (12.58)
Overall	71.05 (9.51)	83.33 (8.86)	70.44 (10.41)	83.95 (7.79)	77.56 (9.67)	82.51 (10.67)	79.58 (10.05)	81.73 (11.40)

Table 4. *Aggregate mean score differences by exam version and overall (across versions) between demographic subgroups as mean and standard deviation (M (SD); n=44).*

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There was a significant and large main effect of subgroup for two of the demographic variables: first generation ($F(1, 42) = 15.32$, $p < 0.001$, $\eta^2 = 0.27$) and low income ($F(1, 42) = 21.80$, $p < 0.001$, $\eta^2 = 0.34$); however, there was no significant difference for the racial/ethnic/cultural minority or female/feminine/woman subgroups. A comparison of the means indicated that students who identified as first generation had lower performance than students who did not identify as first generation. Similarly, students who identified as low income had lower performance than students who did not identify as low income. In contrast, students identifying as members of racial/ethnic/cultural minority groups and students identifying as female/feminine/woman performed comparably to their non-identifying peers. In summary, students from all subgroups performed better on the student-created exams than on the instructor-created exams; however, students identifying as first generation and/or low income performed significantly below their counterparts on both versions of the exam.

Discussion

The current study explored the use of student-created MCQ exams as a constructivist assessment strategy aligned with the principles of inclusive teaching and learning. Results indicated that students in the sample performed significantly and substantially better on student-created exams than instructor-created exams in a human physiology course. This result is consistent with previous research findings that student performance is better on student-created exams (Jobs et al., 2013; Papinczak et al., 2012). However, in contrast to previous studies, students in the current study did not have access to the complete bank of student-created MCQs, and thus could not simply have memorized the questions and answers prior to the exam.

In terms of exam quality, the two versions in the current study were similar in terms of discrimination and were moderately to strongly correlated with each other. This result is comparable with research that found student- and instructor-created MCQ exams to have similar discriminability (e.g., Pham et al., 2023; Schullo-Feuller et al., 2014). However, student-created exams in the current study had a relatively larger percentage of "easy" questions and a relatively smaller (albeit not statistically significant) percentage of questions that required higher-order cognitive skills. These findings are also consistent with previous studies on student-created MCQ exams. For example, Jobs and colleagues (2013) found that student-created questions in their study were less difficult than lecturer-created questions. Pham et al. (2023) found that student-authored MCQs were less difficult and less cognitively complex than the clinician-authored MCQs, though Pham and colleagues noted that the quality of items authored by both groups was not optimal. As in previous research, it is possible that students' superior performance on the student-created exams in the current study was in part attributable to a higher percentage of "easy" questions that required relatively lower-order cognitive skills. To address this concern, future applications of student-created exams may benefit from providing students with guidance on how to craft MCQs that are appropriately challenging and that tap into higher-order cognitive skills. In addition, more extensive vetting of student-created MCQs by the instructor may be needed to ensure that the question pool has an appropriate range of difficulty and complexity.

A second aim of the study was to explore demographic subgroup differences in performance on student-created exams. This aim was prompted by a substantial body of research that raised concerns about the disproportionate participation of females (e.g., Kong et al., 2020) and members of underrepresented minority groups (e.g., Estrada et al., 2016) in STEM disciplines. Although the percentages of both females and members of underrepresented minority groups in the STEM workforce increased within the past decade (National Center for Science and Engineering Statistics, 2023), members of these groups continue to experience complex inequities in STEM education that may contribute to their underrepresentation within master's and doctoral programs and within specific STEM careers. For example, in their review of research on the gender gap in achievement in math-intensive STEM fields, Wang and Degol (2017) highlighted cognitive, attitudinal, motivational, and sociocultural factors that contribute to female underrepresentation in such STEM fields as mathematics, computer science, and engineering. Among these factors, sex-related stereotypes and biases (implicit or explicit) may play a particularly problematic role in negatively shaping women's views of their own self-efficacy in STEM. Similarly, underrepresented students face challenges to their persistence in STEM education that encompass barriers at the societal, institutional, curricular, classroom, and individual levels (Estrada et al., 2016).

Although systemic solutions to these challenges are essential, equally important are classroom-level interventions, such as teaching and learning strategies that support historically marginalized students. Within the context of anatomy and physiology education more specifically, there is growing recognition that creating a learning environment that values diversity and inclusion requires educators to be more intentional about using equitable assessment practices (Meyer & Cui, 2019). Such practices strive for fairness in the assessment process, thereby allowing all students the opportunity to demonstrate their learning.

In the current study, students who identified as members of one or more historically underrepresented demographic groups demonstrated improved performance on student-created exams, compared to instructor-created exams. The difference between performance on student-created and instructor-created exams was comparable for all subgroups, underrepresented or not. However, members of two subgroups (first generation or low income) did not

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achieve the same level of performance as their peers on either the student-created or instructor-created version. This indicates that additional work is needed to make the assessment process more equitable for these groups. Examples of equitable assessment strategies include using multiple measures of student learning, providing frequent feedback, and communicating high expectations for all students (Qualters, 2016). Such strategies support a more culturally responsive assessment process, which Walker et al. (2023) describes as "incorporat[ing] flexibility and choice so that students can leverage their own cultural perspectives to demonstrate their mastery of a given subject area" (p. 4). This current study highlights one assessment technique designed to do so.

Strengths of the current study include standardized exam and question creation procedures, which are easily repeated. Randomization of test questions for exam inclusion minimized selection bias, and randomization of version assignment by creator (A or B) minimized the effect of testing fatigue. Further strengths of the study include blinding participants to exam version creator and results during testing as well as blind rater assessment of question difficulty to further minimize selection bias.

Limitations of the study include a relatively small, predominantly female cohort. Future studies should build upon this pilot study with larger, more evenly distributed samples to replicate and extend the current results. Because exam content was limited to MCQs and written predominantly at lower cognitive levels, generalizability to other exam formats and content depth is limited. Indeed, the current study did not address the common critique that multiple-choice questions typically assess recall of foundational knowledge, which may hinder students' development of critical thinking skills (Stanger-Hall, 2012). Therefore, future research should explore student co-created assessments that require deeper engagement of higher-order cognitive skills. Furthermore, each student had access to their own questions and briefly saw at least one other student's questions while performing peer review, which could contribute to improved performance on student-created exams. However, the odds of including any single question on the exam were small (about 5%) and no violations of the student honor code for sharing either student- or instructor-created test banks were reported.

Conclusion

The current study suggests that student-created MCQ exams have potential as a constructivist assessment tool. Students performed significantly better on student-created exams, both versions discriminated similarly, and both were moderately to strongly correlated with each other. However, student-created exams in the current study had a relatively larger percentage of "easy" questions, and more instruction on writing MCQs requiring higher-order cognitive skills may be needed. Students who identified as first generation and/or low income performed significantly higher on student-created exams, but did not achieve the same level of performance as their peers on either the student-created or instructor-created version. This indicates that additional work is needed to make the assessment process more equitable for these groups.

In the current study, creating MCQs required students to engage differently with the course material, formulate appropriate question and response options, and collaborate with peers to refine their questions. Student-created MCQs also provide a bank of test questions useful to assess foundational knowledge, thus freeing the instructor to create culturally responsive assessments that require higher-order cognitive skills. As such, student-created MCQ exams may serve an important role as part of a comprehensive assessment plan. Additional research is needed to determine whether students' co-creation of exam questions resulted in longer-term learning of course content, which would suggest that student-created exams are useful assessments *of* learning and *for* learning.

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About the Authors

Laura S. Kabiri, PT, DPT, PhD is an assistant teaching professor in the Department of Kinesiology at Rice University. Her main teaching responsibilities include human anatomy, human physiology, and medical terminology. Her research interests include educational experiences and assessment in undergraduate STEM courses, particularly among underrepresented minorities.

Catherine R. Barber, PhD is an assistant teaching professor and associate director of the Center for Teaching Excellence at Rice University. Her teaching and research interests include exploring the intersection of cognitive, social, and emotional aspects of learning; using evidence-based strategies for developing effective and engaging online courses and workshops; and implementing action research to improve teaching and learning.

Thomas M. McCabe, PhD is an assistant teaching professor and associate director of the Center for Teaching Excellence at Rice University. His research and teaching interests include post-secondary biology education research, professional development, and curricular design.

Augusto X. Rodriguez, PhD is an associate teaching professor and chair of the Department of Kinesiology at Rice University. His areas of expertise include research design and statistical analysis.

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Cultivating a Scientific Mind in Undergraduate Students: Redesign of an Introductory Anatomy and Physiology Laboratory

Maureen E. Dunbar, PhD and Jacqueline J. Shade, DC

Division of Science, The Pennsylvania State University – Berks, Reading, PA, USA

Corresponding author: med18@psu.edu

Abstract

Teaching introductory anatomy and physiology (A&P) requires a careful balance of conveying core content while at the same time fostering a deep interest in the subject matter. This is especially true in the laboratory where students are expected to not only master experimental procedures but also connect what they learn in the laboratory to course content. Traditional laboratory courses often have students follow "cookbook" style procedures. While these lab activities expose students to specific techniques or equipment, they are often at the expense of a deeper understanding of the content. The core concepts of physiology were developed to allow students to engage with course content in ways that build an integrated, conceptual understanding applicable to multiple physiological topics. In this article we describe the redesign of an undergraduate A&P laboratory course structured around three core concepts: scientific reasoning, structure/function, and systems integration. These concepts provide a framework whereby students can more effectively transfer concepts from one system to another. The course was redesigned into a "flipped" format in which students are first exposed to content prior to lab and laboratory activities were restructured to be inquiry- and problem-based. The goal of these curricular changes was to shift the focus from mastery of technical skills and declarative knowledge towards fostering critical thinking and clinical reasoning skills. An approach to the laboratory that includes the interrelated functional importance of systems and structures can create an engaging class atmosphere and deepen student's interest in the complex world of physiologic function. https://doi.org/10.21692/haps.2024.009

Key words: laboratory redesign, flipped course design, scientific reasoning, structure/function, systems integration

Introduction

Introductory physiology courses are challenging not only for students but also for faculty. Students struggle with the integrative and conceptual nature of the subject matter and faculty are challenged to find the appropriate balance of conveying content while fostering a deep interest in the subject matter. Core concepts are comprehensive ideas that can provide a framework to help students master anatomy and physiology (A&P) in a way that moves the learner beyond memorization of facts to a deeper understanding of the connected nature of physiological systems. The core physiology concepts are a set of 14 topics, designed by physiology educators, that can be applied across all physiological systems. (Goodman, 2018; Michael & McFarland, 2020). These concepts, along with their conceptual frameworks, have been utilized for course design (Crosswhite & Anderson, 2020; Hull et al., 2017), program design and assessment (Michael & McFarland, 2020; Stanescu et al., 2020), and textbook organization (Amerman, 2021; Silverthorn, 2015). While there are a few instances of faculty members adopting core concepts in the classroom (Chirillo et al., 2021; Crosswhite & Anderson, 2020; Michael, 2021; Stanescu et al., 2020), there is a dearth of information for faculty interested in redesigning laboratory courses around the core concepts.

In this article we describe the redesign of an introductory laboratory course in A&P structured around three core concepts: scientific reasoning, structure/function relationships, and systems integration. These concepts are routinely used by physiologists to organize and assess information to make connections between physiological

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systems. We specifically chose these three core concepts as the framework for our course redesign as they allowed us to shift the educational goals from memorization of content and mastery of technical skills toward fostering higher-level cognitive and clinical reasoning skills (Goodman, 2018). For students to demonstrate mastery of physiology, they must be able to transfer knowledge from one context to another (Barnett & Ceci, 2002; Goodman, 2018; Michael & McFarland, 2020). Transfer can occur more effectively when courses are designed in such a way that students are able to recognize the relationships between concepts and they are given multiple opportunities to practice applying the core concepts (Barnett & Ceci, 2002). By repeatedly relating the course content back to the three core concepts, and by having students be active participants in the learning process, they can more readily apply their knowledge of those concepts to other systems (Goodman, 2018; Michael & McFarland, 2020).

The specific inclusion of these three concepts in the framework for our redesign in no way negates the importance of the other core concepts, nor does it preclude the inclusion of them in the classroom. The three core concepts were selected because they allowed us to design laboratory activities that incorporated multiple opportunities for students to (1) practice scientific reasoning skills, (2) emphasize how structure gives rise to and is related to function, and (3) demonstrate how multiple systems are functionally related (Michael & McFarland, 2020). Figure 1 illustrates the how the three core concepts were used as the lens through which the course was restructured. In this model, all laboratory activities revolve around inquiry- and/or problem-based learning in which students actively engage with the core concepts as a way to transfer acquired knowledge to multiple systems (Goodman, 2018; Michael, 2006).

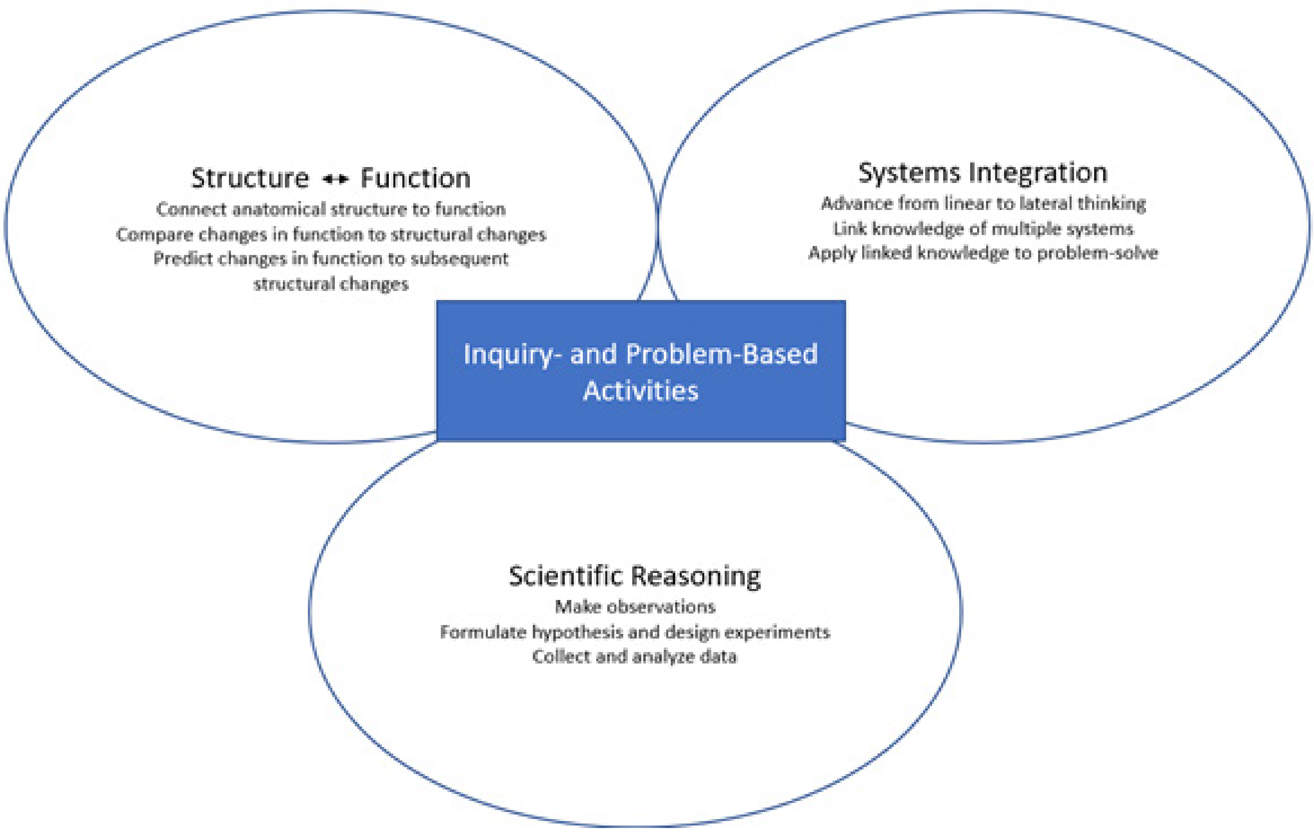

Figure 1. *Model depicting the framework used in the course redesign to an inquiry- and problem-based model centered around three of the core concepts of: structure/function, systems integration, and scientific reasoning.*

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Course Redesign

The A&P course described here is an introductory, two-semester course taught at a branch campus of a large state university. A&P is offered as two, three-credit lecture courses (A&P I and II) each linked to a one-credit laboratory course and enrolls a mixture of first- and second-year students majoring in allied health professions (nursing, occupational therapy, kinesiology) as well as upper-level students preparing for graduate school. Student backgrounds are quite diverse with some students having no prior science courses, and others having more extensive backgrounds. The course objectives (Table 1) are established by the university and are intended to be clear, concise statements of what learners will be able to demonstrate at the end of the course.

1. Develop and demonstrate a vocabulary of biological terminology to communicate information related to anatomy and physiology effectively.
2. Recognize and identify anatomical structures and evaluate physiological functions of each structure / organ system.
3. Recognize and explain the principle of homeostasis and the use of feedback loops to control physiological systems in the human body.
4. Recognize and explain the interrelationships within and between physiological systems of the human body.
5. Use anatomical knowledge to predict physiological consequences and use knowledge of function to explain the features of anatomical structures.
6. Apply knowledge of anatomy and physiology to real-world situations, including clinical cases, health and lifestyle decisions, and homeostatic imbalances.
7. Demonstrate laboratory procedures used to examine anatomical structures and evaluate physiological functions of each organ system.
8. Interpret and explain different types of anatomical images and graphs/ figures of physiological data.
9. Communicate clearly both verbally and in writing an understanding of the human body

Table 1. *Course Learning Objectives for Introductory Anatomy and Physiology.*

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Historically the introductory A&P lab courses at our campus were taught using a traditional one-system-at-a-time approach. Laboratory sessions were in person for four hours each week (2 hours, twice weekly) and students worked in groups of four. Students would receive a short lecture on relevant background and procedures and then would perform the lab activity following detailed step-by-step instructions. Rarely did students benefit from any prior exposure to the topic or content for the day. Once the lab activity was completed, students would analyze the data individually outside of class. Student understanding of anatomical structures and technical skills was assessed using practical exams, and physiological concepts were assessed through formal lab reports. While this course design exposed students to technical and, on occasion, clinical skills, students were not explicitly required to transfer what was learned from one week to the next or from one application to another (Michael & McFarland, 2020). Program assessment data indicated that while the traditional approach to lab was effective in teaching students an extensive vocabulary in A&P as well as recognizing and identifying anatomical structures, students were not adequately prepared to discuss the relationships between physiological systems, predict consequences of structure/function changes, or apply that knowledge to real world situations (unpublished data).

When we set out to redesign the laboratory course, our first goal was to utilize the three core concepts as a semester-long framework with which to organize learning activities. These concepts would be used as a conceptual framework with which to organize a hierarchy of smaller ideas to make up a concept (Michaels & MacFarland, 2020). Our second goal was to encourage critical thinking and clinical reasoning skills. Because most students enrolled in these courses enter a clinical setting following graduation it was imperative that our teaching methods reflect a consistent intent to foster clinical analytical skill. This goal was developed following the recommendations and practices discussed in Teaching Clinical Reasoning and Critical Thinking: From Cognitive Theory to Practical Application (Richards et al., 2020). Specific care was taken to encourage clinical and critical reasoning not just explicitly, but implicitly by modeling clinical reasoning and problem solving. Our third goal was to engage students in the learning process and make them responsible for their learning. The learning activities and classroom climate had to be such that conditions were favorable to learning. Our last goal was to demonstrate the relevance of physiological systems to everyday life.

To meet these goals, an inquiry- or problem-based approach was adopted. Studies examining the relationship between student learning and modes of teaching have repeatedly shown that active learning such as inquiry- and problem-based approaches, are more effective than lecture alone. (Alaagib et al., 2019; Alkhasawneh et al., 2008; Casotti et al., 2008; Richards et al., 2020) Although there has been a push in recent years towards inquiry-based learning, many physiology lab courses are still using the traditional approach (Frisch et al., 2018; Michael & McFarland, 2020; Rehorek, 2004). These conventional style labs do not necessarily provide an opportunity for students to develop their own understanding of physiology using scientific reasoning or to apply the content to their daily lives. By creating an environment that engages students in the scientific process, students can achieve more meaningful learning and they can apply their understanding to multiple systems simultaneously (Michael, 2006; Michael & McFarland, 2020). By giving students a conceptual framework that can be broadly applied, the new approach will continue to serve students in graduate and clinical settings where they must be motivated and able to critically assess information and analyze multiple organ systems and complex processes (National Research Council, 2000; Richards et al., 2020).

An inquiry- or problem-based approach to lab typically means reducing the body of knowledge to be acquired (Goodman, 2018). This approach allows the focus to be on core concepts rather than rote memorization of facts so that students are better able to understand how organ systems work together in a complex organism (Michael & McFarland, 2020; Stanescu et al., 2020). While each body system is covered in lecture, for lab we selected activities for those body systems that had clinically relevant topics that we thought would be of interest to students at the introductory level. Table 2 provides a summary of several of the redesigned labs and how the three core concepts were used for each body system. For example, when discussing digestive disorders, students are not only learning about the structure/function of the digestive system, but they are also learning that proper digestive system function impacts multiple body systems. When studying vision (or any of the special senses), incorporating a multisensory activity instead of simply focusing on anatomy allows students to gain a better appreciation for the integration of multiple sensory inputs and how they produce our perceptual reality (Dunbar & Shade, 2021). By discussing lumbar disc injuries students not only connect anatomical structure to function, but they also learn how changes in function can lead to subsequent structural changes.

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Body System	Revised Curriculum	Previous Curriculum
Digestive System	*Topic: Celiac Disease and Other Digestive Disorders* SR: Hypothesize how tissue damage to small intestine would lead to symptoms of celiac disease. Why did grain-based diets foster the emergence of celiac disease? SF: Model the anatomy of the digestive system using clay. Discuss how the unique structure of organs might dictate their function (example: how do villi increase surface area and what purpose would that serve?) SI: Discuss how tissue damage in celiac disease affects the function of other systems. Discuss the extraintestinal manifestations that are commonly seen. CO: 1, 2, 3, 4, 5, 6, 9	Digestive System Anatomy (Cat dissections) CO: 1, 2, 8
Nervous System	*Topic: Auditory and Visual Reaction Times* SR: Design your own experiment to challenge auditory or visual reaction time. SF: Discuss how structures like the cochlea and photoreceptor cells are designed for transduction. SI: Explain how visual and auditory stimulus are converted into electrical signals, which are processed in the central nervous system. Discuss how action potentials then produce muscle contraction and movement. CO: 1, 2, 4, 6, 8, 9	Basic Neuroanatomy (Cat dissections) Reflex and Reaction Time (Computer Simulations) CO: 1, 2, 7, 8
Musculoskeletal	*Topic: Lumbar Disc Herniation* SR: Hypothesize how lumbar disc degenerative changes or injury would lead to various symptoms. SF: Build clay models of muscles. Explain how disc changes create subsequent functional changes. SI: Discuss how degenerative changes/injuries to the disc impact the nervous system. Discuss active rehabilitative exercises that impact neuromuscular structures. CO:1, 2, 4, 6, 8, 9	Musculoskeletal anatomy (Cat dissections) CO: 1, 2, 8
Special Senses	*Topic: Crossmodal Perception* SR: Hypothesize the impact of vision and olfaction on taste perception, and the impact of vision on scent perception. SF: Examine similarities of transduction in vision, olfaction and gustation. SI: Demonstrate neural integration by studying how vision impacts taste perception, how olfaction impacts taste perception, and how vision impacts olfactory perception. CO: 1, 2, 3, 4, 8, 9	Basic anatomy of sense organs (Examination of plastic models) Basic clinical examination (Tuning forks, opthalmoscope, etc.) CO: 1, 2, 8

Table 2. *Body systems in the previous and revised curricula. SR = scientific reasoning, SF = structure function, SI = systems integration, CO = course objectives met.*

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In addition to an inquiry-based design, we also employed a flipped classroom model (Al-Samarraie et al., 2020). In a flipped design (also called hybrid design) students are first exposed to course content outside of the classroom, thereby allowing them to engage with the content on a deeper level (Abeysekera & Dawson, 2015; Al-Samarraie et al., 2020; Awidi & Paynter, 2019; Gilboy et al., 2015; Kang & Kim, 2021; Sadik & Abdulmonem, 2020). Face-to face time is spent on active learning with collaborative learning being an important part of the process (Abeysekera & Dawson, 2015). Courses in which students are asked to read and complete assignments before coming to class and have active collaborative activities have been shown to improve student learning. (Awidi & Paynter, 2019; Kang & Kim, 2021; Sadik & Abdulmonem, 2020).

Laboratory courses are an ideal place to incorporate a flipped design because the lab involves significant preparation by the student prior to in-class meetings. Face-to-face time can then focus on problem-based (Alaagib et al., 2019; Alkhasawneh et al., 2008; Richards et al., 2020) and active, multi-sensory learning activities (visual, auditory, read-write, kinesthetic) (Alkhasawneh et al., 2008; Baykan & Naçar, 2007; Breckler & Yu, 2011; Wagner, 2014) that are designed to effectively stimulate multiple learning styles.

Each lab module follows the basic flow chart illustrated in Figure 2. Students are first exposed to course content by engaging in e-learning activities. These activities, ranging from textbook readings to instructor created online videos, are designed to focus on the first level of Blooms taxonomy – or the *knowledge domain* (recall of basic facts, terms and basic concepts) (Krathwohl, 2002). Online pre-lab quizzes are used to assess basic competency with subject knowledge prior to face-to-face meetings. During face-to-face time, students work in small groups to engage in collaborative laboratory activities designed to focus on higher levels of Blooms taxonomy – *application, analysis, synthesis and evaluation* (Krathwohl, 2002). At the conclusion of each module student learning is assessed through group presentations, informal class discussions, or group quizzes. Group quizzes have been shown to be an effective tool to stimulate meaningful learning because they require students to articulate their understanding of the subject matter and to respond to challenges (Jensen et al., 2002; Michael, 2006; Slusser & Erickson, 2006).

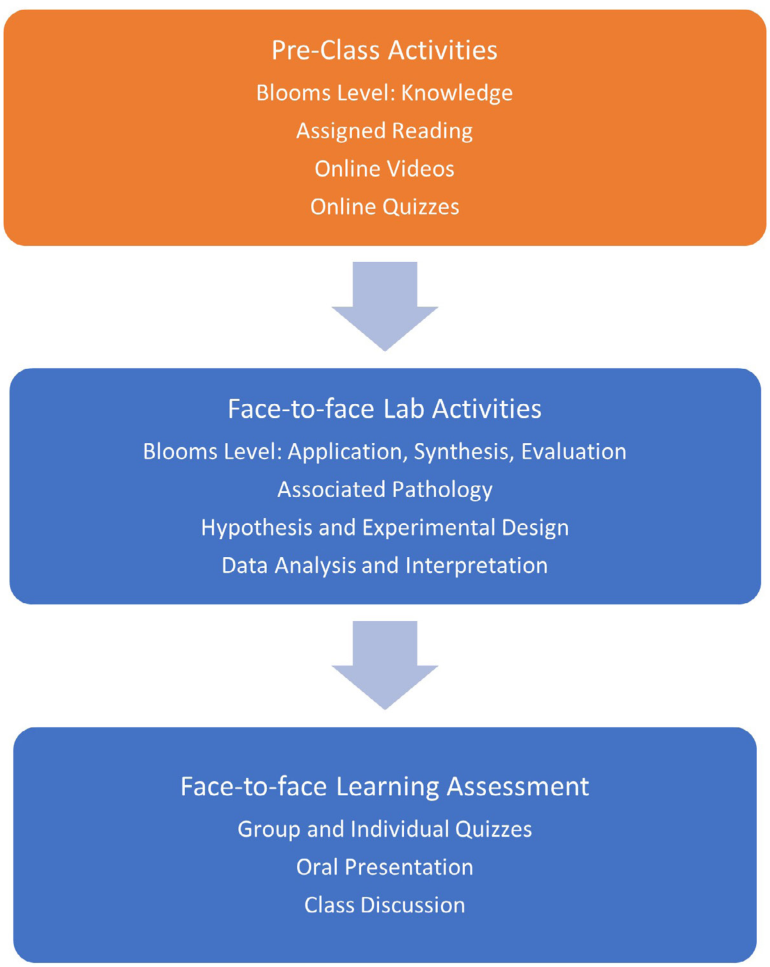

Figure 2. *Flow diagram illustrating the basic organization of each lab module.*

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Below, we provide a detailed example of a laboratory module that was redesigned around the three core concepts. We are hopeful that this framework will allow other instructors to tailor the content of their courses in such a way that students are given multiple opportunities to ask and answer questions (scientific reasoning), explore relevant connections between structure and function and solve problems that require the transfer of knowledge to multiple physiological systems.

Example of Course Redesign: Musculoskeletal System

Prior to the redesign, the musculoskeletal system lab utilized cat dissections to introduce students to the origin, insertion, innervation and action of muscles. Over the course of several weeks, students dissected preserved cat specimens and labeled pertinent structures. While the dissections allowed students to visualize the muscle tissue, the lab activities focused mainly on memorization of structures and relevant facts rather than the relationship between the structures and their functional relevance to other systems. In our experience, students were focused on making lists and finding pneumonic devices to memorize anatomic terms, but they failed to understand the relationships between the structures, or their relevance to other systems and, opportunities to hypothesize as a group were very limited.

When redesigning lab activities for the musculoskeletal system we wanted to create a learning environment that focused on open-ended questions relating content to the three core concepts. In the redesign, the spinal portion of the musculoskeletal system is studied over a two-week period. During the first week students focus on the structure/function of the musculoskeletal system by studying the origin, insertion, innervation, and actions of muscles. Prior to class, students are introduced to the musculoskeletal system through an online human cadaver dissection program. After completing the online activities, students take an online quiz that is designed for two purposes: (1) allow students more practice with the material and (2) assess their understanding of the content prior to the face-to-face lab. During lab, students work in small groups to build muscles with clay on small skeletons. Once the models are completed the students are quizzed as a group on the origin, insertion, innervation, and actions of the muscles, as well as the related osseous structures. Research has indicated the efficacy of utilizing anatomic representations of human structures when learning human anatomy, and that clay modeling effectively provides a kinesthetic and sensory method of learning that students subjectively prefer (DeHoff et al., 2011; Motoike et al., 2009). Group discussion is encouraged prior to answering each question so that disagreements can be adequately investigated. This step often leads to interactions where students must process their thoughts and articulate them to their peers, thereby either creating a greater level of confidence in their response or a realization that further study is needed.

During the second week of the spinal-musculoskeletal module, we expand the focus to include systems integration and more advanced scientific reasoning by studying lumbar disc degeneration and herniation. By utilizing a common pathology, we are able to pose a series of questions and develop possible answers, as students acquire new information that they can then relate back to content that was previously learned (Barnett & Ceci, 2002). Other reports have shown that this approach allows the focus to remain on causal relationships and improves the depth of understanding of the A&P being studied (Goodman, 2018).

Before coming to lab, students read a primary research article on lumbar disc injuries (Freeman et al., 2010). This article was selected because it can be understood by undergraduate students, and it provides an opportunity to integrate the three core concepts. For example, this paper introduces concepts such as deep stabilizing muscles and their functional importance (structure/function), why small muscles with a high cross-sectional area would function more as stabilizers rather than producers of motion (structure/function, scientific reasoning) and how afferent feedback subsequent to pain/injury might lead to reflex muscle inhibition and impede proper muscle activation (systems integration) (Freeman et al., 2010). By shifting the focus away from a simple model of disuse leading to weakness, and instead evaluating evidence suggesting that pain and neurologic dysfunction can lead to subsequent tissue changes, students are encouraged to utilize greater levels of critical thinking (Freeman et al., 2010). Additionally, students were given a PowerPoint presentation in which the stages of several progressive exercises were demonstrated for them, first on a stable base and then on a labile base. Students were required to work as a group and then bring to class their own example of a progressive exercise that they demonstrate or present to the class.

The face-to-face portion of this lab is divided into three parts: review of lumbar anatomy, introduction of imaging studies, and a learning activity involving rehabilitative exercises and stability balls. We begin the lab with a review of lumbar anatomy utilizing pictures from open educational resources as visual aids. In this portion of lab more in depth content related to lumbar discs is covered. Once students are introduced to greater complexity in structures, then open-ended questions can be explored that focus on function and pathology to stimulate critical thinking and clinical reasoning. In this process students are encouraged to view functional spinal units as a whole rather than as separate structures (Freeman et al., 2010).

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The questions in Table 3 are examples of the types of questions that can be asked in this portion of class. The questions posed during lab are dictated, in part, by student responses on any given day; therefore, not all questions will be asked in every class period. By asking questions, students can explore and discuss answers allowing them to practice their newly acquired knowledge of musculoskeletal anatomy and relate that knowledge to the pathology of lumbar disc injuries. Instructors demonstrate modeling of scientific reasoning by asking how/why questions to improve students critical thinking skills (Richards et al., 2020). This approach has been shown to improve the depth of understanding of the system being studied (Goodman, 2018). As questions are asked and answered throughout class, students are encouraged to focus on the relationship between the content and the three core concepts.

How does the basic composition and structure of the disc (the concentric lamella of the annulus fibrosus (AF) and the gelatinous nucleus pulposus (NP)) dictate its function? Why is the study of these structures and of lumbar disc herniation (LDH) important clinically? (SR, SF)
When viewing the neural foramen in relation to the disc or facets, can you visualize how any encroachment from nuclear material or osseous growths could create direct pressure on neural structures and resultant neurologic symptoms? What types of symptoms might be seen in this scenario? What types of pathophysiological mechanisms might be involved in pain generation? (SR, SF, SI) This is a straight-forward observation but a necessary step towards progression to understanding clinical symptoms that result from issues that do not involve direct mechanical compression.
Can you see why changes in the proteoglycan content of the nucleus might impact the hydrostatic pressure and therefore alter load distribution and mechanical forces? What about tears in the lamella of the annulus or end plate junction failures? With these types of degenerative changes what changes might be seen in that functional spinal unit over time? Why might a patient suffer a disc herniation even in the absence of any specific trauma? (SR, SF)
How might a reduction in blood supply to the disc change the integrity of the tissue over time? (SR, SF, SI)
If we continue this reasoning, as motion is limited, what changes might occur as the body attempts to stabilize the area? How would ankylosing of the motion segment impact the region above or below? (SR, SF)

Table 3. *Examples of questions that can be asked during the face-to-face lab activities and their relationship to the core concepts. (SR = scientific reasoning, SF = structure/function, SI = systems integration)*

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Once relevant structures are reviewed and located on the Open Education Resources visual aids, focus is shifted to transfer that knowledge to imaging studies in the second part of lab. Lumbar anatomy is reviewed on X-ray as well as in the midsagittal and axial planes on MRI. Many online resources are available to offer clear visual content of the lumbar region. One excellent reference which includes high quality visual imaging that demonstrate both normal anatomy and various pathologies can be found at: https://www.radiologymasterclass.co.uk/. This site includes a gallery section with examples of x-rays demonstrating various traumatic injuries as well as accurately labeled lumbar MRI studies of both normal anatomy and pathology. Images from the research paper that students studied prior to class (fatty infiltration into the multifidus muscles after injury) are also reviewed as a class. Sample questions and related content for this portion of the lab, and their connection to the core concepts, can be found in the supplemental materials.

In the third and final part of lab, utilizing knowledge that they gained earlier in the module, students explore and perform exercises to examine how these types of injuries might be rehabilitated. The exercises become increasingly more challenging by progressing from a stable to an unstable base, via the use of stability balls. Students demonstrate their own progressive exercises to the class and all students are given the opportunity to participate in the activity to their level of ability. Some students simply sit on the ball with a progressively narrower point of contact by moving their feet closer together while others complete more advanced exercises. These exercises allow students to be actively engaged in the learning process and provide an opportunity for students to practice scientific reasoning skills. Sample questions for this final part of lab, and their connection to the core concepts, can be found in Appendix 1.

Summary

In this article, we have described the redesign of our A&P laboratory courses from traditional labs to inquiry- and problem-based labs structured around three core concepts: structure/function, systems integration and scientific reasoning. By using these three concepts to create a framework to organize course content, we are able to shift the focus of the course from the mastery of technical skills to the development of higher-level cognitive skills. By creating a learning environment that challenges students to ask and answer complex questions, and by repeatedly relating the course content back to the three core concepts, students actively participate in processing new knowledge that they are then able to transfer to novel situations (Alaagib et al., 2019; Goodman, 2018). With this approach, instructors at other institutions should be able to focus the content of any lab around their specific areas of expertise while still utilizing the recommended format to focus on semester-long core concept themes.

An important aspect to the lab redesign was using a flipped course design. In traditional A&P courses, students are exposed to course content by listening to lectures and carrying out step-by-step procedures in lab. Students tackle the more difficult tasks of application of the material themselves through homework assignments or written lab reports. In a flipped course, students engage with the material outside of class so that they are prepared for an active, collaborative learning experience inside the classroom or lab (Gilboy et al., 2015). Without having first exposure to the basic content knowledge gained through pre-class activities, there would not be enough time during face-to-face lab meetings to focus on the higher levels of Blooms taxonomy. The example provided for the musculoskeletal lab illustrates the depth with which content can be covered, provided the students come to lab with a solid understanding of basic content (assessed via an online pre-lab quiz).

While we have not yet formally assessed student learning in the redesigned course, student comments have been positive. Students claimed that they enjoyed the engaging atmosphere of the labs and that they felt more motivated to learn the material. Since the redesign of the musculoskeletal module, several students have expressed an interest in careers in medical radiation technology and radiology while other students have incorporated stability ball exercises into their daily activities. While this is anecdotal, we are encouraged by the level of interest and engagement of students during the labs.

About the Authors

Maureen Dunbar, PhD, is an associate professor and Chair of the Biology Program at The Pennsylvania State University – Berks College. She teaches introductory and advanced courses in cellular and molecular biology and developmental biology. Her research focuses on the effects of estrogen and PTHrP on mammary gland development. Jacqueline Shade, DC, is an assistant teaching professor at The Pennsylvania State University – Berks College. She teaches A&P 1 and 2, both lecture and lab. She has spent more than 20 years in private practice focusing on spinal joint mechanics.

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Appendix 1. Sample laboratory questions and their connections to core concepts

Sample Questions	*Related Core Concepts*	Content Introduced by Exploring these Questions
How does the basic composition and structure of the disc (the concentric lamella of the annulus fibrosus (AF) and the gelatinous nucleus pulposus (NP)) dictate its function? Why is the study of these structures and of lumbar disc herniation (LDH) important clinically? *(Part 1 of Disc Pathology Lab)*	*Scientific Reasoning, Structure-Function*	The gelatinous NP has a high concentration of proteoglycans and therefore attracts and binds water. This is important to the discs mechanical/compressive properties and ability to exert pressure in all directions and manage compressive loads. Low back disc pain is a very common problem in the 20-50-year-old age group, as the disc undergoes extensive degenerative changes. It is a leading cause of pain and disability. The maintenance of spinal motion is critical to pain reduction as well as the preservation of normal lifestyle activities. (Errico, 2005; Priyadarshani et al., 2016)
When viewing the neural foramen in relation to the disc or facets, can you visualize how any encroachment from nuclear material or osseous growths could create direct pressure on neural structures and resultant neurologic symptoms? What types of symptoms might be seen in this scenario? What types of pathophysiological mechanisms might be involved in pain generation? *(Part 1 of Disc Pathology Lab)*	*Scientific Reasoning, Structure-Function, Systems Integration*	Pain can occur in the location of pathology, as most students would suspect, but symptoms may also occur at other sites and may have different pathophysiologic mechanisms. Students begin to see that pain may be generated not only by mechanical compression but also damage to nociceptive tissue from local degenerative changes as well as inflammatory mediators. Students can link symptoms that occur in other systems to LDH, such as a loss of bowel/bladder control. By following the scientific reasoning involved in central sensitization, students can see how sensory changes can occur as the result of processing issues, even in the absence of direct mechanical pressure. (Freynhagen & Baron, 2009)
Can you see why changes in the proteoglycan content of the nucleus might impact the hydrostatic pressure and therefore alter load distribution and mechanical forces? What about tears in the lamella of the annulus or end plate junction failures? With these types of degenerative changes what changes might be seen in that functional spinal unit over time? Why might a patient suffer a disc herniation even in the absence of any specific trauma? *(Part 1 of Disc Pathology Lab)*	*Scientific Reasoning, Structure-Function*	Over years, degenerative changes at the nucleus, annulus and end plates may occur with the development of scar tissue and mechanical changes. As subclinical failures occur a patient may suffer from LDH even in the absence of any trauma. This allows students to further contemplate avenues of treatment and rehabilitation that address biomechanical changes that are not readily visible. The concept of cumulative trauma injuries of the lumbar spine in the absence of any specific major event brings to the students awareness of the concept that pathology can arise from a slow cascade of events. This level of processing of information and the ability to connect lecture content to lab content, rather than memorization of unrelated facts more closely resembles clinical practice and the required reasoning. (Newell et al., 2019; Rajasekaran et al., 2013; Suri et al., 2010; Tavakoli et al., 2020)
How might a reduction in blood supply to the disc change the integrity of the tissue over time? *(Part 1 of Disc Pathology Lab)*	*Scientific Reasoning, Structure-Function, Systems Integration*	Disc tissue can begin to break down over time and may begin in the second decade of life. A reduction in blood supply occurs as early as the early 20's and results in the degradation of disc tissue. This content relates directly to the specific demographic that is frequently seen in college classrooms making the content relevant to the students. It also reminds students of the critical importance of proper blood supply to the health of all tissues. (Boos et al., 2002)
If we continue this reasoning, as motion is limited, what changes might occur as the body attempts to stabilize the area? How would ankylosing of the motion segment impact the region above or below? *(Part 1 of Disc Pathology Lab)*	*Scientific Reasoning, Structure-Function*	Disc height is lost, and vertebrae may lose their appropriate alignment to adjacent vertebrae. Anterior or posterior slippage can cause direct mechanical pressure (a different mechanism than they previously discussed) Osteophyte formation occurs as well and may result in fusion of the motion segment. This can lead to further changes at adjacent motion segments as they become hypermobile to compensate. This leads to further compensatory degenerative changes. An ability to follow scientific reason past the point of direct correlations is very important to the development of critical thinking. (Boos et al., 2002; Errico, 2005)

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What is the difference between muscle tissue loss from disuse and muscle tissue loss stemming from reflex inhibition of the muscle? Can you combine your knowledge of anatomy and physiology of spinal joints and muscles and your understanding of mechanoreceptors and transduction to give a possible mechanism of how we can see muscle control dysfunction, even if imaging studies do not show any obvious pathology? *(Part 2 of Disc Pathology Lab)*	*Scientific Reasoning, Structure-Function, Systems Integration*	Motor program changes occur due to pain and may remain altered even after pain resolves. Inhibition of the muscle leads to dysfunction and muscle tissue is replaced with fatty tissue. Cumulative trauma results in sub-failure injuries which damage soft tissues involved in transduction. This alters the feedback to the muscles and damages neuromuscular control leading to faulty muscle firing patterns and instability. This leads to further injury and inflammation in the area and the cycle continues. It is not necessary that students memorize this sequence. What is important is that they begin the process of critical thinking, connecting information from different systems and sources, and understanding that answers are not always straightforward. (Freeman et al., 2010; Panjabi, 2006)
How can changes seen in LDH lead to changes in sensory processing and alter proprioception? *(Part 2 of Disc Pathology Lab)*	*Scientific Reasoning, Structure-Function, Systems Integration*	Mechanoreceptor feedback of discs, ligaments and joints, through transduction, control muscle activity and reflexes. Degenerative changes that damage these tissues result in a loss of coordinated feedback, proprioceptive changes and instability. (Akuthota & Nadler, 2004; Izzo et al., 2013)
What other body systems might be involved in compensatory mechanisms that result from proprioceptive changes? *(Part 2 of Disc Pathology Lab)*	*Scientific reasoning, Structure-Function, Systems Integration*	Proprioception and the ability to accurately sense the position of body parts in space requires three bits of information: proprioceptive information, visual input and input from the vestibular system. This is an excellent example that encourages students to see multiple systems as a functional whole. Sensory and sensorimotor changes that impair proprioceptive function will lead to problems with gait and increase the likelihood of falls. Students can now combine all of this information to decide what other systems might provide compensatory mechanisms to stabilize the patient's gait. They can hypothesize how a stooped, shuffling gait might occur as a patient lowers their visual field to see the floor, widens the base of their stance for stability, and does not lift the foot fully off the ground (shuffling). They can even assess the importance of cognition in gait as elderly persons who perform cognitive tasks often stop walking, indicating an increased likelihood of falls. (Johnson et al., 2008; Pirker & Katzenschlager, 2017)
What types of exercises would be beneficial in these types of injuries and functional changes? *(Part 3 of Disc Pathology Lab)*	*Scientific reasoning, Structure-Function*	Muscle weakness as well as delays in proper muscle activation is seen in patients with low back pain and LDH. Core strengthening and improved motor control can help to maintain functional stability. Coactivation of multiple muscle groups and the use of an unstable base (like a stability ball) can improve balance and proprioception and lead to function improvement and stability. (Akuthota & Nadler, 2004; Behm et al., 2005)

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The Influence of an Interdisciplinary Approach on Student Confidence in Undergraduate Anatomy and Physiology

Valerie Weiss, MD, MS, Nicola Khalaf, PSPT, DPT, MBA, Rob Sillevis, PT, DPT, PhD

Florida Gulf Coast University, 10501 FGCU Blvd, Fort Myers, FL, USA

Corresponding author: vweiss@fgcu.edu

Abstract

While many studies have demonstrated a positive correlation between learning in the arts and students' critical thinking disposition, few studies have investigated the influence of an interdisciplinary art-related teaching approach and its correlation with academic student behavior confidence in anatomy and physiology (A&P). Therefore, this study aims to demonstrate the impact of an interdisciplinary approach – reading, discussion, and drawing on students' academic confidence in undergraduate A&P. The investigation utilized a self-reported pre- and post-survey design to explore the change in confidence in A&P between course entry and exit. Sixty undergraduate students completed surveys while taking an elective course called Medical Literature, Anatomy, and the Arts, at a public state university in Southwest Florida. Results indicate a statistically significant difference in student-reported confidence levels in knowledge and experience of A&P. Additionally, the students' perceptions of the course were positive, citing more engagement and better support from peers and instructor as a result of this interdisciplinary approach. These outcomes suggest that teaching undergraduate students in A&P using medical arts enhances student academic confidence. This study provides encouraging support to existing scholarly work on higher education course design and instructional methods relative to improving student confidence and class engagement in A&P. https://doi.org/10.21692/haps.2024.012

Key words: academic behavior confidence, interdisciplinary teaching, anatomy and physiology, art, medical illustration

Introduction

Improving student achievement in higher education by enhancing student academic behavior confidence has been the focus of many theoretical models (Sander et al., 2000; Sander & Sanders, 2003, 2006, 2009). Academic behavior confidence refers to the student's belief in his/her capability to perform tasks required to successfully learn and achieve at the university level. Sander and Sanders (2003) developed the Academic Behavioral Confidence Scale (referred to as the ABC scale) in order to understand variations in teaching preferences and learning behaviors for different groups of students. The ABC scale is useful for educators to grasp their students' proclivities, enabling the design of more effective teaching. Nicholson et al. (2003) extended Sander and Sanders' previous work by demonstrating that students earning higher end-of-semester grades take more responsibility for their learning and are more confident in their studying and class participation. This concurs with the findings of Stankov et al. (2014), who identified that confidence is the best non-cognitive predictor of academic achievement.

Not only does confidence play a role in an undergraduate's success, but so does the innovative delivery of course content, specifically via interdisciplinary, art-based instruction. The study of the arts represents an evidence-based, powerful pedagogical strategy contributing to academic achievement and student success (Ruppert, 2006). Moreover, a growing body of evidence highlights the ways that creativity and critical thinking are interconnected in higher education (Dumitru, 2019).

Ayala et al. (2017) demonstrated that engaging in creative outlets while enrolled in medical school can provide significant benefits to the student's overall well-being. A qualitative study by Jones et al. (2014) at the University of Michigan Medical School found that incorporating artwork into the medical school curriculum had significant positive

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effects on students, including profound personal growth and a greater sense of community. Another study across five U.S. medical schools tested and confirmed the hypothesis that exposure to the arts and humanities enhanced positive personality qualities in medical students, shaping them into more well-rounded and empathetic physicians (Mangione et al., 2018). An exploratory study by Shapiro et al. (2009) at University of California Irvine School of Medicine reported that integrating creative projects into an anatomy course can significantly enhance medical students' ability to reflect on their professionalism and manage stress. Moreover, medical students enrolled at the University of Bristol in the United Kingdom are required to submit creative works for assessment as part of their core curriculum. Thompson et al. (2010) noted that requiring medical students to engage in art projects as part of the standard curriculum can be particularly impactful for those who normally dismiss such activities. By pushing these medical students out of their comfort zones, the curriculum fosters significant personal and professional development.

Less research exists at the undergraduate level about evaluating the effects of creating art to boost students' confidence in the learning of anatomy and physiology (A&P). Moyer (2020) reported on undergraduate students enrolled in A&P courses at Elizabethtown College, who can earn extra credit by making a creative piece highlighting a concept learned throughout the semester. A participant observed that the divide between the sciences and the arts is a misconception and that the combination of the two subjects gave them a creative outlet for the knowledge learned in class and deepened their understanding of the human body. Platt et al. (2021) evaluated the effect of assigning creative projects during a large, undergraduate, two-semester anatomy course to promote student engagement. The authors found that incorporating various forms of innovative expression via drawing, sculpture, or poetry into anatomy coursework is attainable and valuable to a student's education. Finally, Weiss and Casazza (2021) found that an undergraduate course in medical illustration offered during the COVID-19 pandemic allowed students to relax and feel less isolated while simultaneously learning anatomy.

To contribute to the body of evidence supporting the use of art for learning anatomy, this study aimed to demonstrate the impact of an interdisciplinary approach — reading, discussion, and drawing, on students' academic confidence in undergraduate A&P. The following two research questions guided this study:

1. What is the relationship between an interdisciplinary way of teaching undergraduate A&P and students' academic confidence in learning this discipline?
2. What are the perceptions of students enrolled in a course on the use of reading, discussion and drawing as an instructional method for enhancing academic confidence?

Methodology

The work described in this manuscript is the result of an opportunity to design and teach an elective course called Medical Literature, Anatomy, and the Arts at a public state university in Southwest Florida. The curriculum integrates elements of art, medical literature, and A&P to create a multifaceted approach to learning. The course is divided into seven units, each lasting two weeks, and focusing on a specific theme from the assigned reading. The readings are curated from Dr. Atul Gawande's (2002) book, Complications, A Surgeon's Notes on an Imperfect Science.

Student Population

A purposive convenience sampling was used for this mixed method study design. Data was collected from students enrolled in this course during the spring semesters of 2021, 2022, and 2023. All sixty students were invited to complete the pre- and post-survey. Participation was voluntary and without compensation, including receiving any course points for its completion. The course population included 60 students (N), comprised of 4 males and 56 females. While the students varied in grade level and major, most had some interest in a health-related field (e.g., pre-nursing, exercise science, bioengineering, psychology, health science, public health, or biology) as shown in Table 1. Pre-nursing was the most popular major (N=26), followed by health science (N=10).

Freshmen		Sophomores		Juniors		Seniors		Other		Subtotal	
n	%	n	%	n	%	n	%	n	%	n	%
5	8	39	65	7	12	5	7	4	7	60	100

Table 1. *Numbers and percentages of students by grade level.*

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This study was approved by the Florida Gulf Coast University Institutional Review Board (IRB #2021-04) and informed consents were received from all participants.

Description of the Interdisciplinary Course with Curriculum

Medical Literature, Anatomy, and the Arts, is a 3-credit elective course that has no specific prerequisites (students do not need to have taken prior anatomy courses nor drawing classes). Lessons in both anatomy and drawing (with in-class practice) are integrated into seven units with distinct themes created based on the readings (Table 2). The course uses a multi-pronged interdisciplinary approach to learning: reading, discussion, and drawing (Figure 1).

Each unit starts with the students reading a medical-based short story from Dr. Atul Gawande's (2002) book, a thought-provoking collection of stories that delves into the complexities of modern medicine. The idea that every illness has a story highlights the importance of understanding the contextual dimensions of sickness beyond its clinical manifestations. From Gawande's book, the students gain valuable insight into each patient and the human aspect of medical conditions and their treatments. For the class discussion, students anonymously write down an open-ended question pertaining to the assigned reading on a blank note card which further guides sharing of opinions among the class. Active listening is encouraged to build trust and rapport among the students. Students become curious about the patients' stories and their corresponding medical conditions, prompting them to learn more about the relevant anatomy and physiology. The clinical scenario presented in the reading helps students to grasp and apply anatomical knowledge. In this way, Dr. Gawande's storytelling is balanced with presentation of anatomical information, leading to rich and engaging class discussions about medical uncertainties, ethical dilemmas, and, sometimes, the fallibility of doctors.

Course Themes

- Cancer, Mortality, & Difficult Decisions
- Suspicions in Medicine: The Case of Dead Babies
- The Mystery of Appetite and the Science of Hunger
- Autopsy and Medical Discoveries
- Medical Uncertainties and Human Survival
- The Paradox of Medical Training
- Common Symptoms in Medicine: Nausea and Vomiting

Table 2. *Medical literature, anatomy, and the arts course themes.*

After a thorough discussion of the reading and anatomy, hands-on drawing exercises are taught covering the basic principles of illustration such as light, shadow, color, and composition. The drawing lessons allow students to build on their artistic skills, regardless of initial skill level. Instructor-led sketching practice is completed in class, but not for a letter grade, allowing students to learn by receiving immediate feedback. Students are able to start with basic art exercises before progressing to more advanced ones. The culmination of each unit becomes the creation of an original medical illustration with the theme being the reading discussed, the anatomy lesson learned, and the illustration techniques gained. Ultimately, the seven final illustration projects are critiqued and graded for accurateness, decision-making, and innovativeness during the creative process.

The course curriculum, as described in the syllabus with its multi-prong interdisciplinary approach to learning, is outlined in Table 3.

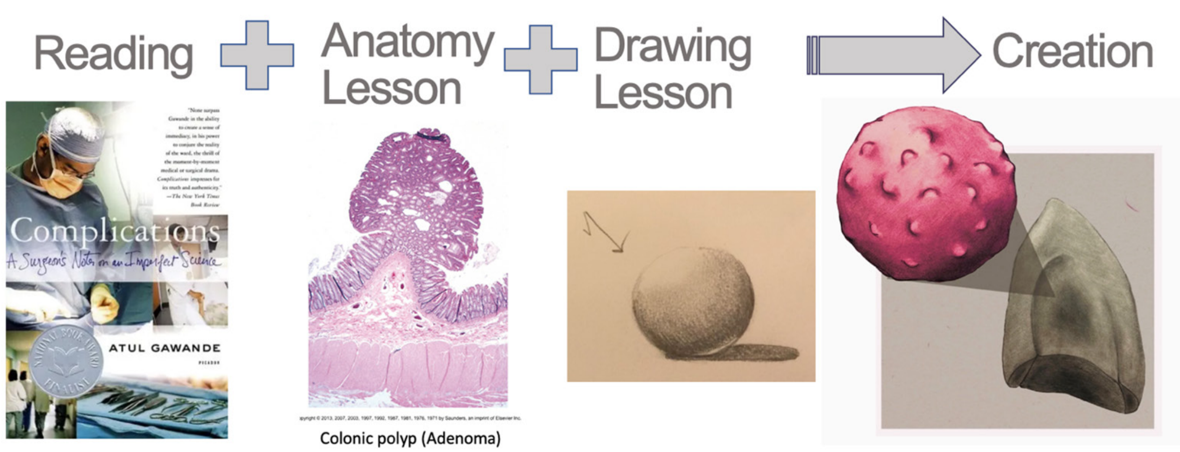

Figure 1. *Multi-pronged interdisciplinary approach to learning.*

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Unit Theme	Reading	Drawing Lesson	In-Class Sketch	Anatomy Lesson	Medical Illustration Project
1. Cancer, mortality, & Difficult Decisions	"Whose Body Is It Anyway?" (pp. 208-227)	Introduction to medical illustration: Light & shadow; Outline & contour; Color & simultaneous contrast	Sketches of spheres with a light source	Introduction to cancer: Biology of tumor growth; Grading & staging; Clinical treatment	Illustrating the story of cancer
2. Suspicions in Medicine: The Case of Dead Babies	"The Dead Baby Mystery" (pp. 202-207)	Patterns, textures, and graphic design; Learning how to use pen & ink	Blindfolded ink designs	Accidents, diseases, & causes of death in children	Patient education piece on child mortality
3. The Mystery of appetite and the Science of Hunger	The Man Who Couldn't Stop Eating" (pp. 162-183)	Introduction to medical legal illustration	Simplifying the stomach for a lay audience	Overview of gastrointestinal anatomy	Medical-legal drawing demonstrating gastric bypass surgery
4. Autopsy and Medical Discoveries	The Final Cut" (pp. 187-201)	Introduction to composition and mixed media	Mixed media flowers	Diseases and illnesses that may be proved by autopsy	Educational piece illustrating a disease which may be discoverable by autopsy
5. Medical Uncertainties & Human Survival	"The Case of the Red Leg" (pp. 228-252)	Experimenting with colored pencils and gradients	Glass marble colored pencil drawings	Anatomy of the skin: Highlights of cellulitis and necrotizing fasciitis	Advanced anatomical education piece of the skin or a skin pathology
6. The Paradox of Medical Training	"Introduction" (pp. 5-8) and "Education of a Knife" (pp. 11-34)	Illustrating arteries vs. veins, Drawing the heart upside down to eliminate preconceived notions	Draw arteries and veins, Basic guided heart drawing	Cardiovascular anatomy	The heart: An iconic organ from Valentine's Day to medicine
7. Common Symptoms in Medicine: Nausea and Vomiting	"A Queasy Feeling" (pp. 130-145)	Introduction to editorial illustrations	Brainstorm editorial sketch of a condition or disease having symptoms of nausea & vomiting	Symptoms of many conditions: Nausea & vomiting	Editorial illustration of a disease or condition with nausea and/or vomiting

Table 3. *Course curriculum, including selected readings from Gawande (2002).*

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A brief description and corresponding sample of projects are included below (Figures 2-9). For example, the theme of the first unit is *Cancer, Mortality, & Difficult Decisions.* Students were assigned to read Gawande's chapter titled, "Whose Body is it Anyway?" This thought-provoking chapter acquaints the reader to a man faced with terminal cancer and the decisions he must face. The drawing lesson for this first unit not only introduced students to medical illustration but also provided a foundation for the fundamentals of drawing, such as light and shadow, outline and contour, as well as color and simultaneous contrast. Following the art lesson, students were directed to observe and sketch light and shadow on a sphere. By lighting a sphere directly, the highlight or whitest area is the brightest part of the sketch. Students were then instructed to draw the core shadow, the dark area on the object that is not reached by the direct light, as well as the cast shadow, the shadow that the sphere casts on the surface upon which it is resting. Finally, students were instructed to observe and draw the reflected light which bounces off the surface and illuminates the shadowed side of the sphere slightly (Figure 2).

The anatomy lesson for the first unit familiarized students with cancer, including a lesson in basic cells, DNA, and cell division. From there, students learned about the biology of tumor growth, cancer's grading and staging, potential causes, as well as highlights of clinical treatment. The culmination of the course's first unit was to illustrate the story of cancer. Because cancer derives from a rogue cell (or sphere), students were encouraged to incorporate knowledge learned from their first in-class sketch into their final illustration piece. Figure 3 demonstrates a sample student drawing from the first unit's project.

The theme of the second unit is *Suspicions in Medicine: The Case of Dead Babies.* This chapter called, "The Dead Baby Mystery," explores the perplexing spike of infant mortality rates in one family. After discussing the reading, students learned how to create patterns and textures with pen and ink such as cross-hatching, stippling, and scumbling. Blindfolded drawing was used as a class exercise to enhance creativity and intuition. Students were blindfolded as a warm-up exercise in order to create a sketch. From there, pen and ink practice could be incorporated by observing the patterns already created and adding to them. To enhance the reading's discussion, students learned about diseases and cases of death in children as a significant public health concern, and the final unit project was to create a patient education piece on child mortality (Figure 4).

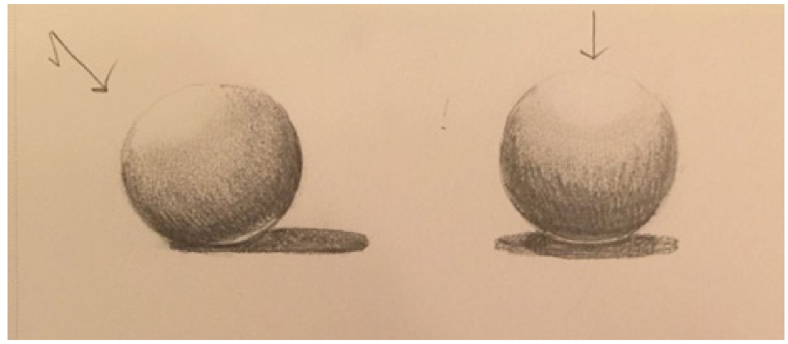

Figure 2. *Illustration: Light on spheres.*

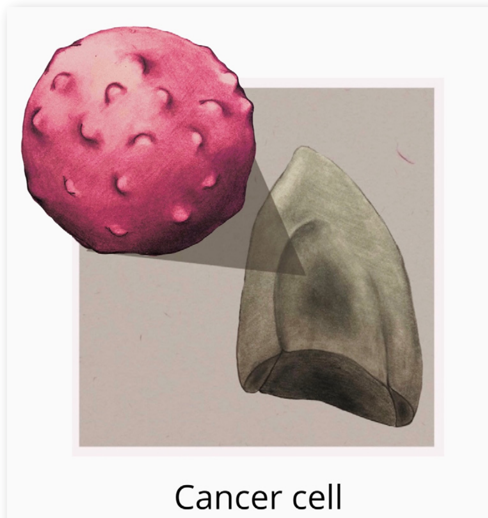

Figure 3. *Illustration: Cancer, mortality and difficult decisions (Credit: Raquel Costa e Silva – A closer look at lung cancer).*

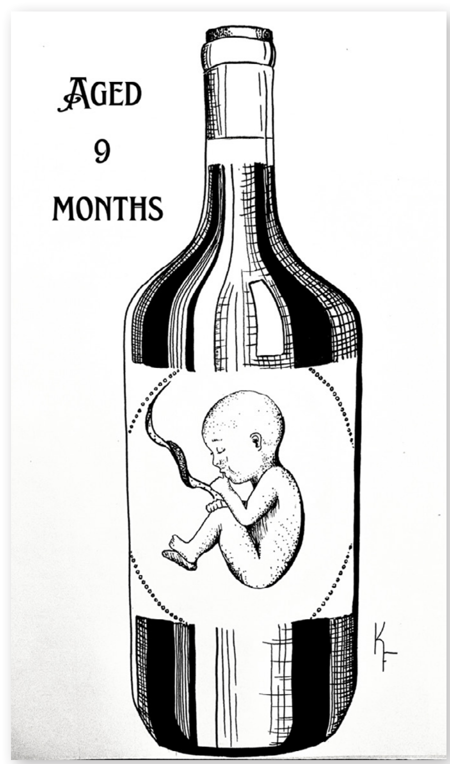

Figure 4. *Illustration: Suspicions in medicine: The case of dead babies (Credit: Katelin Foster – Fetal alcohol syndrome).*

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Unit Three's theme is *The Mystery of Appetite and the Science of Hunger*. Gawande's reading, "The Man Who Couldn't Stop Eating," tells the story of a patient who undergoes gastric bypass surgery in an attempt to address his severe obesity. The class discussion not only focused on morbid obesity as a disease but the challenges and medical considerations that one might face on this journey. The students learned how the body regulates food intake and the structure and functions of the gastrointestinal tract. Students were introduced to medical legal illustration, a specialized field that translates complex medical concepts into clear, compelling images that can be understood by lay audiences, such as juries. Together, sketches of the stomach were completed in class while the final project was to create a medical legal illustration demonstrating gastric bypass surgery (Figure 5).

Autopsy and Medical Discoveries is the theme of Unit Four. Students read Gawande's short story called, "The Final Cut," a compelling read about the human side of medicine, where despite advanced technology and extensive training, there is still unpredictability and human error requiring autopsies. Class discussion focused on autopsies as a detailed examination of a body after death for various reasons: medical education and research, public health and safety, as well as family closure and peace of mind. The drawing lesson for this unit guided students through the basics of composition in art and introduced them to the use of mixed media. By practicing with flowers picked outside, the goal was to help students create visually balanced and engaging artworks by combining different materials and techniques. The final project was to make an educational piece illustrating a disease which may be discoverable by autopsy (Figure 6).

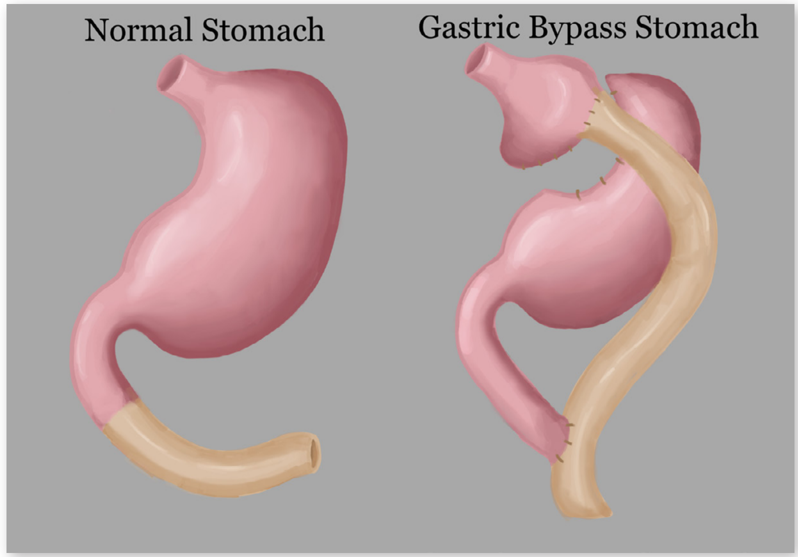

Figure 5. *Illustration: The mystery of appetite and the science of hunger (Credit: Melanie Barrientos – gastric bypass surgery).*

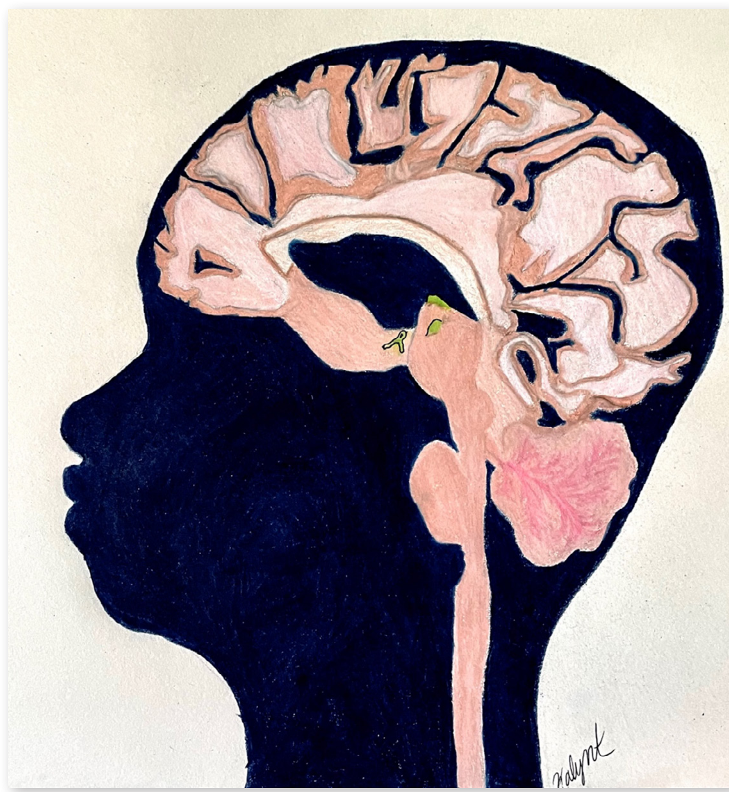

Figure 6. *Illustration: Autopsy and medical discoveries (Credit: Kalyn Alexus – Alzheimer's disease).*

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The next unit's theme focuses on *Medical Uncertainties and Human Survival* after reading, "The Case of the Red Leg." This chapter explores how both doctors and patients navigate the complexities and unpredictability inherent in medical practice when a young woman is faced with a diagnosis of necrotizing fasciitis. Students explored the anatomy of skin and its layers, the subcutaneous tissues, and fascia. By understanding the anatomy of the skin, the distinction between two diagnoses—the more benign cellulitis and potentially deadly necrotizing fasciitis—becomes very clear. In the art lesson, students experimented with colored pencils to create color gradients while making sketches of colored marbles. The goal of this in-class drawing exercise was to advance the students' illustration techniques such as observing, layering, and blending. The final project was to make an advanced anatomical piece detailing a disease of the skin (Figure 7).

The Paradox of Medical Training is the theme of Unit Six. Students were assigned to read Dr. Gawande's "Introduction" as well as the first chapter in his book called, "Education of a Knife." These chapters set the tone of the book by highlighting the inherent uncertainties and imperfections in the field of medicine. In these chapters, Gawande delves into his own training as a surgical resident, exploring the balance between the scientific knowledge gained and the artistry of experience, further illustrating how surgical practice is both a science and an art, requiring a blend of analytical thinking and artistry. This complex theme became the starting point for learning about the heart, an organ that embodies both artistic elegance and analytical complexity. Students gained a comprehensive understanding of cardiovascular anatomy from both an artistic perspective — drawing it upside to eliminate preconceived notions as well as illustrating arteries and veins to illustrate their functions — and an analytical perspective — learning detailed anatomy and blood flow pathways. The final project was to create an illustration that highlighted the aesthetic beauty and intricate functionality of the heart (Figure 8).

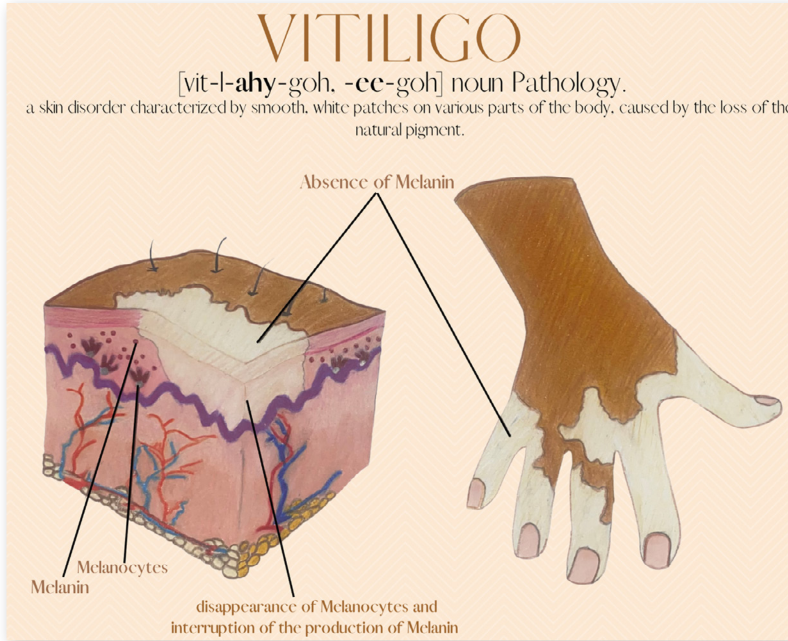

Figure 7. *Illustration: Medical uncertainties and human survival (Credit: Jai-Raelle Whitfield – Vitiligo).*

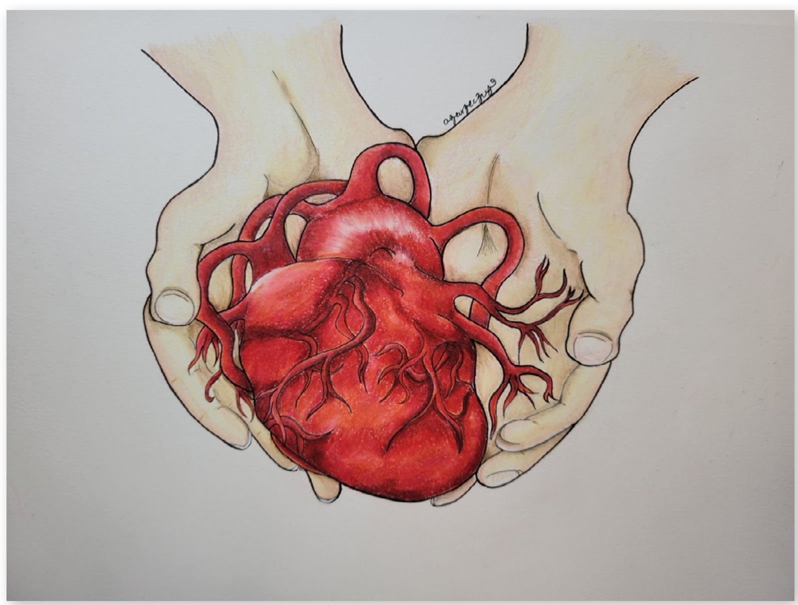

Figure 8. *Illustration: The paradox of medical training (Credit: Angelina Zarzeczny – The heart: An iconic organ).*

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The final unit is on *Common Symptoms in Medicine: Nausea and Vomiting.* "A Queasy Feeling" is another chapter from Atul Gawande's book. In "A Queasy Feeling," a pregnant woman experiences severe morning sickness, a common yet poorly understood aspect of pregnancy. From this reading, students were introduced to the concept of editorial illustrations. These illustrations are used to visually communicate complex ideas and narratives, often accompanying narratives in books or magazines. Students brainstormed about the many conditions in which nausea and vomiting are symptoms and then categorized those causes by organ system and disease. The final project was to create an editorial illustration depicting these symptoms (Figure 9).

Data Collection

Surveys were administered to students on the first day (pre-course survey) and on the last day of the semester (post-course survey). The survey included a 10-point Likert-type scale whereby students rated their confidence level (knowledge and experience of anatomy), with a "10" being the most confident and a "1" being the least confident. Additionally, students provided written comments, providing a deeper understanding of their experiences in the course. (See Appendices 1 and 2).

Data Analysis

The Statistical Package for the Social Sciences software Version 28.0 was used for the quantitative data analysis. Data analysis included the survey responses from 2021, 2022, and 2023 Spring semesters. The survey data reflected a normal distribution.

Therefore, the paired t-test was used for pre and post comparison. The Spearman's correlation coefficient was used to correlate findings. An alpha of 0.05 for all statistical tests was used. Inductive thematic analysis described by Vears and Gillam (2022) guided the analysis of the open-ended questions.

Figure 9. *Illustration: Common symptoms in medicine: Nausea and vomiting (Credit: Taylor Speer – Editorial illustration of experiencing nausea and vomiting).*

Results

Figure 10 demonstrates the increase in the mean ($\pm$ SD) student reported confidence levels from those measured pre-course (7.0 $\pm$ 1.9) to after-course (8.2 $\pm$ 1.6). The paired t-test revealed a statistically significant difference between the pre-course and post-course survey responses (t (59) = 6.8, $p < 0.001$; Table 4). Figure 11 summarizes the frequency of responses for the pre-course and post-course confidence level in anatomy in response to the question "From a scale of 1 (least) -10 (greatest), what is your confidence level of anatomy (knowledge and experience of anatomy)?" The "Always" response increased from 3% (pre-course) to 29% (post-course).

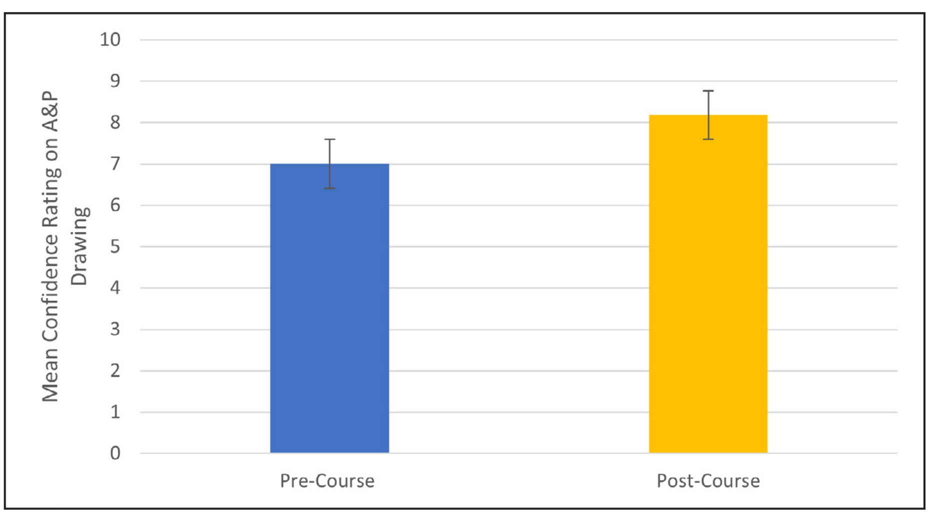

Figure 10. *Student confidence mean and standard deviation pre-course and post-course.*

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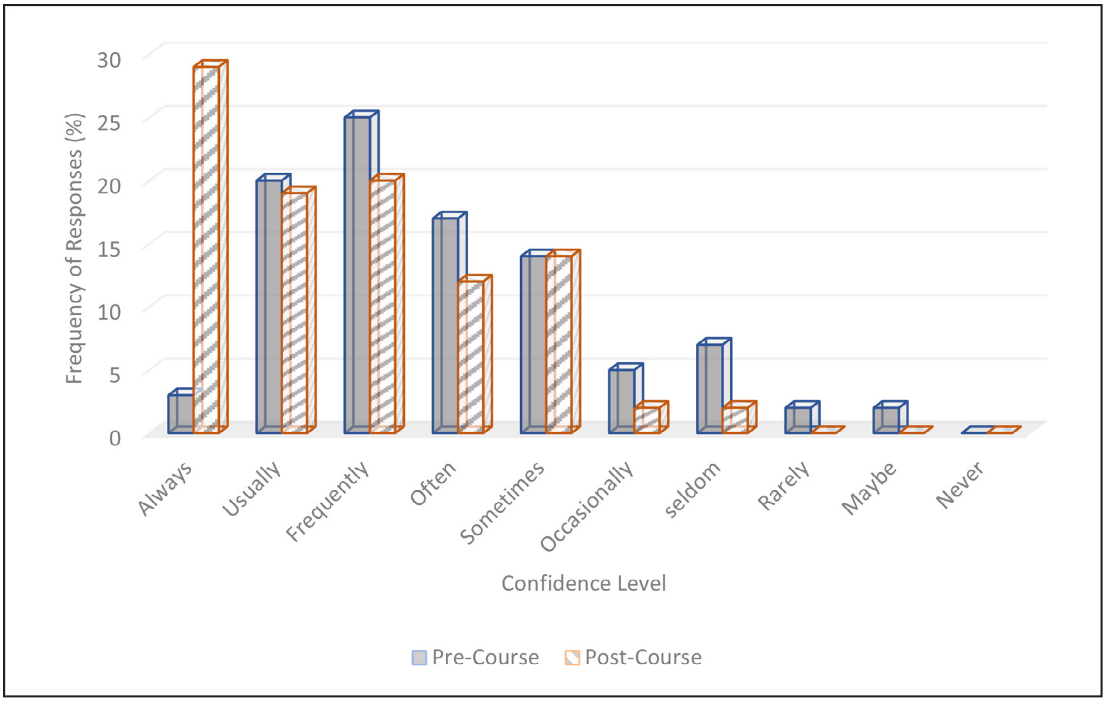

Figure 11. *Pre-course and post-course frequency of Likert scale responses.*

P-value	5.74E-09
Test stat T	6.8069
N	60
Average of difference	1.1833
SD differences	1.3466
Normality p-value	0.003249
A priori power	0.9678
Past hoc power	1
Skewness	0.04157
Cohen's D	0.8788

Table 4. *Paired t-test between pre-course and post-course confidence in anatomy.*

Spearman's correlation coefficient was used to test the correlation between student grade level and pre-course and post-course student confidence levels in anatomy. The results indicate no statistically significant correlation between student grade level and pre-course student confidence, r (58) = 0.132, *p* = 0.165. Similarly, there is no statistically significant correlation between student grade level and post-course confidence r (58) = 0.139, p = 0.288.

An inductive thematic analysis described by Vears and Gillam (2022) was used to review the answers to the open-ended questions. Qualitative responses (n=34) from the open-ended questions revealed three themes related to the students' perception of using reading, discussion and drawing as an instructional method for enhancing academic confidence: learning, engagement, and support.

Within the theme of improved learning, twenty students made comments related to how drawing helped them learn anatomy, such as *"drawing did significantly help me understand anatomy because I was able to immerse myself and learn more about it".* Another student noted how "*drawing the anatomy in each project greatly reinforced my knowledge about each organ and system that we covered".* A second set of fourteen comments described how the course was enjoyable and captivating by *"having assignments that are engaging and always spark a new idea in all of us", "creating amazing*

continued on next page

art pieces throughout the semester", and setting up the class "for anyone to be able to participate". Finally, ten comments such as *"I never felt judged, just supported, and I feel that the positive reinforcement made me do even better", "everyone is just so kind and open-minded, and I thought the environment makes it a great way to learn",* and *"I was a little nervous about being able to pick up all the different drawing techniques we learned, but the slow, learning pace made all skill levels feel welcome"* referenced how the course fostered a supportive environment.

Discussion

Learning A&P can be challenging, especially given the volume of information and the complexity of the human body. While traditional lecture-based approaches have their place, incorporating innovative methods may enhance students' learning experience leading to increased academic confidence.

The purpose of this study was to determine the impact of an interdisciplinary approach—reading, discussion, and drawing on students' academic confidence in undergraduate A&P. The primary research question centered around how the creative interdisciplinary teaching influenced student confidence levels in the learning of A&P. The results of this investigation provide encouraging support for anatomy instructors as well as institutions that offer A&P. Given that many students struggle with A&P taught in a traditional format, uncovering creative tactics to facilitate student learning while enhancing academic confidence is helpful. The findings indicate that teaching undergraduate A&P via an interdisciplinary approach—reading, discussion, and drawing, positively impacts student academic confidence in knowledge and experience of anatomy. Just as the famous early medical illustrators such as da Vinci and Michelangelo learned the human body by studying and drawing from human cadavers, it seems only natural that reading medical-based literature, learning the relevant anatomy, and creating illustrations could be a reimagined way of teaching and learning in the 21st century. The improved rate of *"Always"* responses to the post-course survey compared to that of the pre-course survey indicated student self-confidence in knowledge and experience of anatomy improved following participation in an interdisciplinary approach to learning.

The secondary research question centered around the relationship between perception of participating in the Medical Literature, Anatomy and the Arts course and enhancing academic confidence. This study's results agree with past research on the utilization of creative works for learning and assessment as part of the required core curriculum in which students' perceptions were positive (Thompson et al., 2010). Additionally, students in this investigation reported more engagement and better support from peers and instructor as a result of the interdisciplinary approach. These results are consistent with previous research (Platt et al., 2021; Weiss & Casazza, 2021), demonstrating that creative projects allowed students to stay engaged, relax, and feel less isolated while simultaneously learning anatomy.

This study is unique in its pedagogical approach and multi-disciplinary course design. Instructor-facilitated group discussions guided students' reflection of the readings. Interactive A&P lessons reinforced the material learned from the reading. Additionally, various illustration techniques were taught in class, tailored to medical illustration. Practice drawing assignments, with hands-on instructor-guided exercises, were then completed as a group. Although grades were not given for the practice drawing exercises, the final culmination of each unit was an original, graded medical illustration which contributed to the final course grade. Students were evaluated on their illustrations for technical accuracy, creativity and presentation, as well as comprehension and reflection of the unit's theme. Throughout the course, open dialogue was encouraged in a collaborative environment.

This investigation was limited by an absence of test or quiz assessments in the course, which could have demonstrated differences in pre- and post-course knowledge and experience of A&P. The inclusion of assessment(s) in the curriculum could have provided more robust evidence to support this study's findings. Without these assessments, it may be challenging to quantify the academic impact of this investigation. Moreover, this study was limited by the number of students (n=60) and their uneven gender distribution, with only 4 males and 56 females. The skewed gender ratio somewhat reflects the Florida Gulf Coast University's gender distribution of 42% male versus 58% female compounded by more female students choosing majors in pre-nursing and health science. Regardless of how the imbalance in gender enrollment occurred, there was no correlation between gender and confidence levels pre- and post-course. Another limitation of the study was that the student surveys were not completed anonymously. This could have introduced bias, as students may have felt pressure to report positive results. Future research could aim for a larger and more balanced student sample with formal test assessments to demonstrate knowledge of A&P earned in addition to confidence gained.

continued on next page

Conclusion

Regardless of these limitations, one theme is clear: integrating an interdisciplinary approach (reading, discussion, and drawing) in the teaching and learning of undergraduate A&P positively impacted student academic confidence in knowledge and experience gained. Students were able to immerse themselves in their learning, become more engaged, be creative, and ultimately become more confident in the discipline of A&P.

About the Authors

Valerie Weiss teaches undergraduate anatomy and physiology at Florida Gulf Coast University. She designed the curriculum for the course in Medical Literature, Anatomy and the Arts. As a trained medical illustrator, her research interest is in using drawing to enhance her students' anatomy education. Nicola Khalaf teaches undergraduate anatomy and physiology at Florida Gulf Coast University. Her passion for teaching anatomy and physiology is superseded only by her enthusiasm for student success in the course. Rob Sillevis teaches in the Doctor of Physical Therapy program at Florida Gulf Coast University. He has a long-standing interest in student success and how the classroom experience can be optimized.

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Appendix 1. Student Pre-Questionnaire for Medical Literature, Anatomy, and Arts Course

Name: ___________________________________

1. What is your current major? ___________________________________

2. What year are you? ____

3. What is your reason for taking this course? ____

4. Do you already know someone in this course? or Are you looking to make new friends?
____

5. By taking this course, is there any topic or skill you are particularly interested in learning this semester?

____

6. On the scale below 1 (least) -10 (greatest), how often do you DRAW for enjoyment?

1 (Never)	2 Maybe once	3 Rarely	4 Seldom	5 Occasionally	6 Sometimes	7 Often	8 Frequently	9 Usually	10 Always

7. On the scale below 1 (least) -10 (greatest), how often do you READ for enjoyment?

1 (Never)	2 Maybe once	3 Rarely	4 Seldom	5 Occasionally	6 Sometimes	7 Often	8 Frequently	9 Usually	10 Always

8. From a scale of 1 (least) -10 (greatest), what is your confidence level of anatomy (knowledge and experience of anatomy)?

1 I know nothing	2	3	4	5	6	7	8	9	10 I've had advanced A&P or am an SI leader for A&P etc.

9. From a scale of 1 (least) -10 (greatest), how confident are you in your drawing skills?

1 I'm not confident with drawing at all	2	3	4	5	6	7	8	9	10 I'm extremely confident when it comes to art

10. From a scale of 1 (least) -10 (greatest), how confident are you in your ability to draw anatomy (produce medical illustrations)?

1 I'm not confident with drawing medical illustrations at all	2	3	4	5	6	7	8	9	10 I'm extremely confident when it comes to medical illustration

Please turn over the paper and write down anything you would like to share with Dr. Weiss ☺

continued on next page

Appendix 2. Student Post-Questionnaire for Medical Fiction, Anatomy, and Arts Course

Name: ___________________

1. What is your current major? ___________________________________

2. What year are you? ____

3. What was your reason for taking this course? ____

4. Did you meet anyone in class (or feel like you were part of this class community)?

____

5. By taking this course, was there any topic or skill you particularly liked learning this semester?

____

6. AFTER TAKING THIS CLASS, On the scale below 1 (least) -10 (greatest), how often do you think you will draw for enjoyment?

1 (Never)	2 Maybe once	3 Rarely	4 Seldom	5 Occasionally	6 Sometimes	7 Often	8 Frequently	9 Usually	10 Always

7. AFTER TAKING THIS CLASS, On the scale below 1 (least) -10 (greatest), how often do you think you will read for enjoyment?

1 (Never)	2 Maybe once	3 Rarely	4 Seldom	5 Occasionally	6 Sometimes	7 Often	8 Frequently	9 Usually	10 Always

8. AFTER TAKING THIS CLASS, From a scale of 1 (least) -10 (greatest), what is your confidence level of anatomy (knowledge and experience of anatomy)?

1 I know nothing	2	3	4	5	6	7	8	9	10 I've had advanced A&P or am an SI leader for A&P etc.

9. AFTER TAKING THIS CLASS, From a scale of 1 (least) -10 (greatest), how confident are you in your drawing skills?

1 I'm not confident with drawing at all	2	3	4	5	6	7	8	9	10 I'm extremely confident when it comes to art

10. AFTER TAKING THIS CLASS, From a scale of 1 (least) -10 (greatest), how confident are you in your ability to draw anatomy (produce medical illustrations)?

1 I'm not confident with drawing medical illustrations at all	2	3	4	5	6	7	8	9	10 I'm extremely confident when it comes to medical illustration

Please turn over the paper and write down anything you would like to share with Dr. Weiss about this class. ☺

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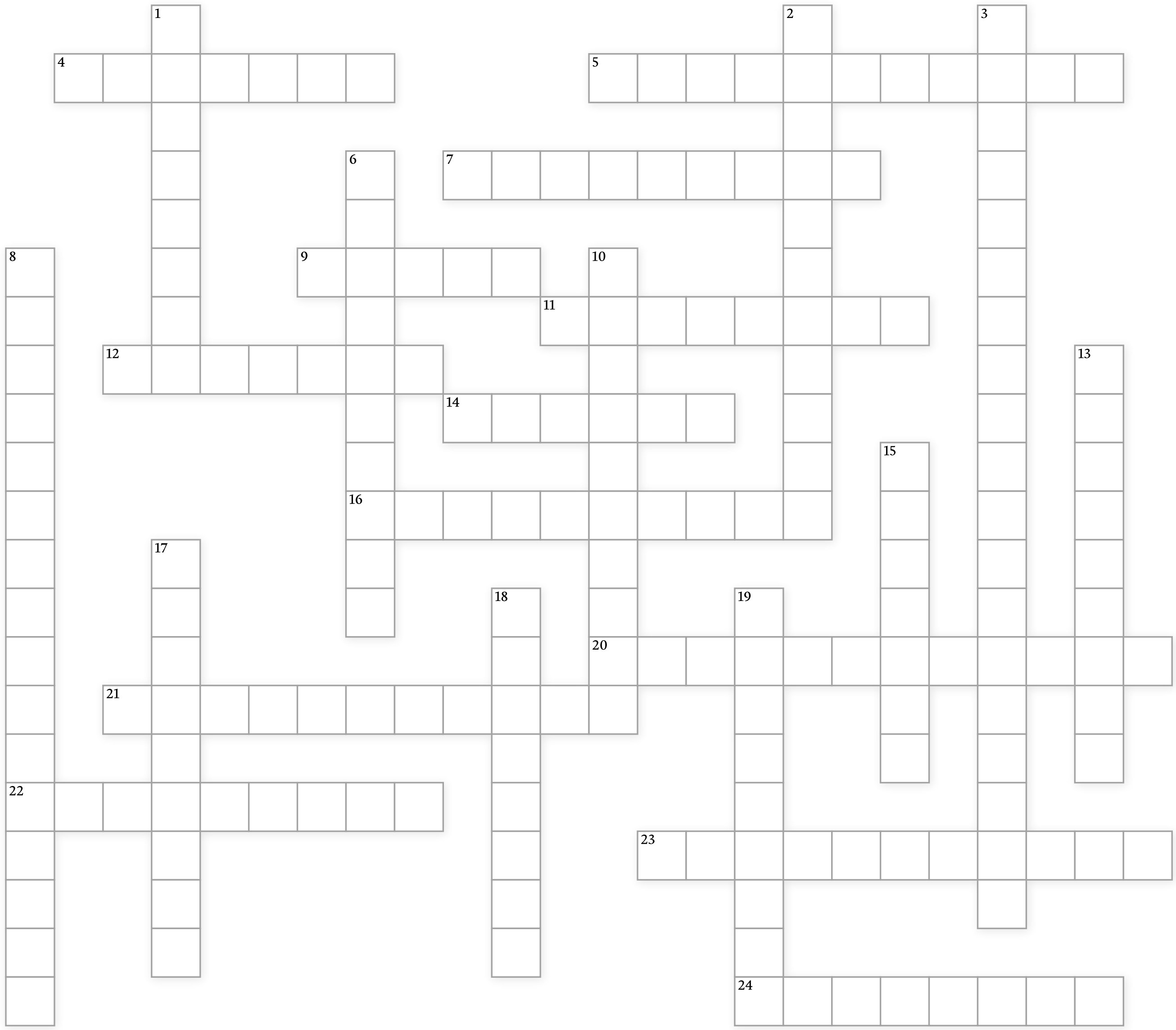
HAPS Educator Crossword 2: Muscles of the Head, Neck and Torso

(For an online version CLICK HERE.)



ACROSS

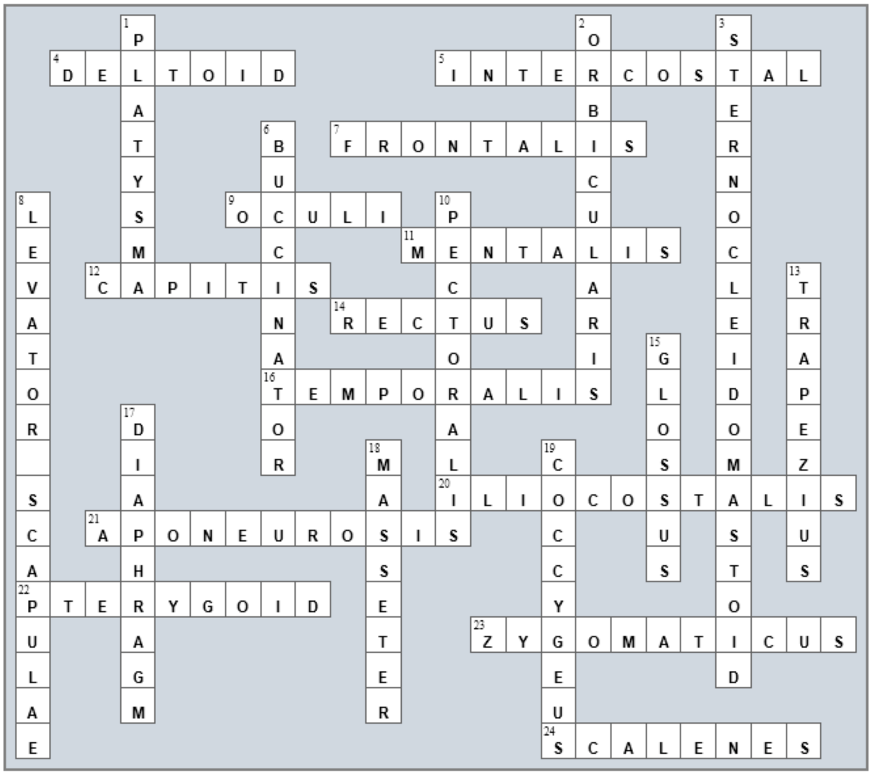
4. Multipennate muscle that is a prime mover of upper limb abduction.
5. .... muscles (internal and external) are found between the ribs.
7. You use this muscle when raising yor eyebrows in surprise.
9. This word in the name of a muscle means that it is associated with the eye.
11. You use this muscle when pouting.
12. This word in the name of a muscle means "toward the head region".
14. There is a .... abdominis and a .... femoris.
16. Convergent muscle that helps keep the jaw closed at rest.
20. The most lateral of the erector spinae muscles.
21. The epicranial .... covers the top of the head to connect two muscle bellies.
22. The name of this group of muscles that are involved in side-to-side grinding movements of the mandible means "wing-like".
23. The smiling muscle.
24. These muscles originate on cervical vertebrae and insert on to the first two pairs of ribs.

DOWN

1. Superficial muscle that tenses the skin of the neck.
2. Two facial muscles have this as the first part of their name - an eye muscle and a lip muscle.
3. Neck muscle whose name identifies the origins and insertion.
6. Horizontal cheek muscle that is well developed in nursing infants.
8. The name of this muscle (2 words separated by a space) tells you that it raises the shoulder blades.
10. The .... major is a fan-shaped chest muscle that can medially rotate the upper limb.
13. Superficial muscle of the posterior thorax whose name tells you its shape when the two triangular halves come together.
15. This word in the name of a muscle means that it is associated with the tongue.
17. This muscle is the prime mover of resting levels of inspiration.
18. Muscle from zygomatic bone to ramus of mandible that is a prime mover of jaw closure.
19. This muscle plus the levator ani combine to form the pelvic diaphragm.

CLICK HERE for Answer Key

Answer key for: Crossword 2. Muscles of the Head, Neck, and Torso (from previous page)



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