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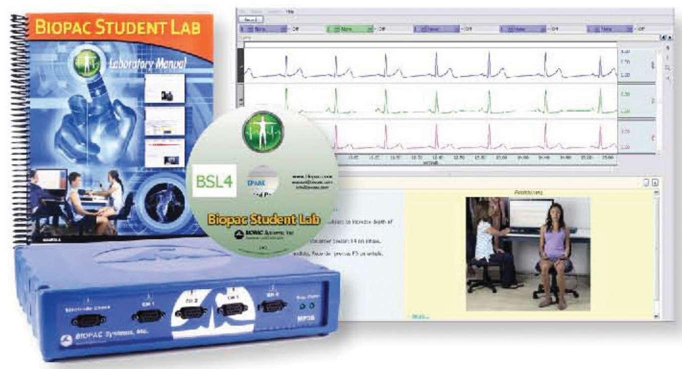

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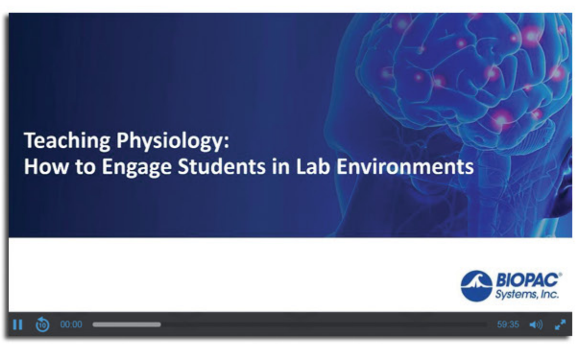

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Hips Don't Lie: Expert Opinions Guide the Validation of a Virtual 3D Pelvis Model for Use in Anatomy Education and Medical Training

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Abstract
Virtual three-dimensional (3D) anatomical models have become popular in the education of students in graduate and undergraduate-level anatomy courses, including anatomy and physiology. There is a need for more research on the effectiveness of these models on student learning, especially in anatomy and physiology, and on the validation of the models implemented in anatomy education. This study focuses on the development of a list of criteria for validating 3D models of the pelvis, using a four-round Delphi method. The Delphi method successfully confirmed the validity of the final list of pelvic criteria, each item with an item content validity index (I-CVI) ≥ 0.83. The average scale content validity index (S-CVI/Ave) of the entire list was calculated to be rigorously valid (0.92). These valid pelvic criteria will be used in future studies to inform additions to an existing virtual 3D model of the pelvis and validate completed virtual 3D pelvic models. https://doi.org/10.21692/haps.2018.023

Key words: anatomy education, virtual 3D models, pelvic models, Delphi method, medical training

Introduction
Anatomy education has undergone many changes throughout its history. One such change has been the implementation of virtual 3D anatomical models in teaching diverse cohorts of anatomy students. Virtual 3D anatomical models have been shown to be beneficial to students of anatomy in both medical (Qayumi *et al.* 2004, Nicholson *et al.* 2006, Brown *et al.* 2012, Cui *et al.* 2017) and dental programs (Maggio *et al.* 2012). Thus, virtual 3D anatomy models of structures in intricate or small areas of the body can be used to improve medical student retention of the corresponding anatomical information.

In addition, virtual 3D anatomical models show promise in undergraduate anatomy education in both undergraduate medicine (Hisley *et al.* 2008, Marsh *et al.* 2008, Müller-Stich *et al.* 2013) and kinesiology (Hoyek *et al.* 2014). Womble (1999) showed that undergraduate students in an anatomy and physiology course favored the use of virtual 3D anatomy, but more research is needed to determine the impact of virtual 3D anatomy on undergraduate education in anatomy and physiology.

In medical education, 3D anatomical models are frequently used to help medical trainees master human anatomy. In the clinical setting, virtual 3D models are used to guide residents and physicians in devising optimal surgical approaches, accessing specific anatomical regions, and excising or repairing structural pathology. These virtual 3D models are especially useful for elucidating complex anatomical regions, such as the pelvis which is a confined space with limited access via dissection. A few studies describe the construction of virtual 3D pelvic models (Beyersdorff *et al.* 2001, Parikh *et al.* 2014, Sergovich *et al.* 2010), and one in particular describes the impact of physical and virtual 3D pelvic models on medical education (Khot *et al.* 2013). However, the validation of pelvic models has not been reported. A review study by Azer and Azer (2016) asserts a need for reporting the validation of 3D models and the assessment instruments used in educational studies for evaluating their impact on learning.

Since there are variations among 3D models, there is a need for consistent, valid anatomical models. In order to ensure the creation of valid anatomical models, an assessment instrument for measuring the validity of 3D models such as the pelvis can be generated using expert opinions. One of the first steps in acquiring expert opinions utilizes the Delphi method, which involves administering a series of two or more rounds of questionnaires to a team of experts in a particular field or discipline (Dalkey and Helmer 1963, Helmer 1967, Caves 1988, Hasson and Keeney 2011, Lisk *et al.* 2014). Lisk *et al.* (2014) used the Delphi method to establish a list of criteria for anatomical structures to include in a curriculum of musculoskeletal anatomy for training residents in Physical Medicine and Rehabilitation.

The validity and reliability of the instrument itself needs to be considered in the process of gathering information for its construction. Hasson and Keeney (2011) cite a number of studies emphasizing the fact that there is controversy over the validity and reliability of the Delphi method. There are also sources that assert the validity and reliability of the Delphi method (Helmer 1967, Caves 1988).

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Although Hasson and Keeney (2011) mention a number of different types of validity and reliability to consider in the use of the Delphi method, one in particular known as content validity is highly emphasized in this study. A number of articles have demonstrated the importance of considering the content validity in the construction of scales or instruments (Lawshe 1975, Waltz and Bausell 1981, Lynn 1986, Davis 1992, Polit and Beck 2006). Polit and Beck (2006) offer a number of suggestions for the reporting of content validity, including the importance of differentiating between item-level and scale-level content validity. While the former refers to the validity of the information within each item on an instrument, the latter refers to the overall validity of the entire instrument. Determining content validity on both levels requires the calculation of a value known as the content validity index (Lawshe 1975, Polit and Beck 2006), and the calculations for both the item-level content validity index (I-CVI) and the scale-level content validity index (S-CVI) are described by Polit and Beck (2006). The item-level and scale-level content validity will be the primary focus of this paper as they are expressly relevant to the construction of criteria lists of pelvic anatomical structures that are important to consider in teaching pre-health and medical students, as well as medical residents.

The purpose of this article is to describe in detail the Delphi method used to develop a list of valid criteria for validating 3D anatomical pelvic models, the steps that will be taken to generate additional structures to incorporate into an already existing virtual 3D pelvic model based on experts' feedback, and the target audiences for such a model. In addition, this article aims to address the lack of reporting of the validity of created anatomical models and assessment instruments in the literature.

Methods

Context

This study was conducted at the University of Mississippi Medical Center (UMMC), a large, urban academic medical center in the southeastern United States. This institution serves as the only academic medical center in the state, making it a critical entity for educating most of the state's healthcare professional students in a number of programs, including medicine, dentistry, nursing, pharmacy, graduate studies, population health, and other allied health fields. Several of these disciplines rely heavily on anatomical education that consists of traditional lectures, laboratory experiences, and active learning sessions. Virtual 3D anatomy has been implemented specifically in the medical gross anatomy and medical neuroscience and behavior courses as independent, voluntary 3D learning sessions, but these learning experiences have not yet been fully integrated into the anatomy courses. This study will describe steps toward validating a set of virtual 3D anatomical models through the development of valid criteria for a pelvic model. The Delphi method was implemented in four rounds to gather expert opinions for developing the list of criteria. The particular Delphi procedure used was a classical method in the sense that it incorporated more than three rounds of administrations beginning with an open-ended, qualitative session (Hasson and Keeney 2011). However, similar to the modified Delphi design, the expert responses were collected in the subsequent rounds using a variety of methods (Hasson and Keeney 2011), including in-person interviews, online communications, and paper-based surveys.

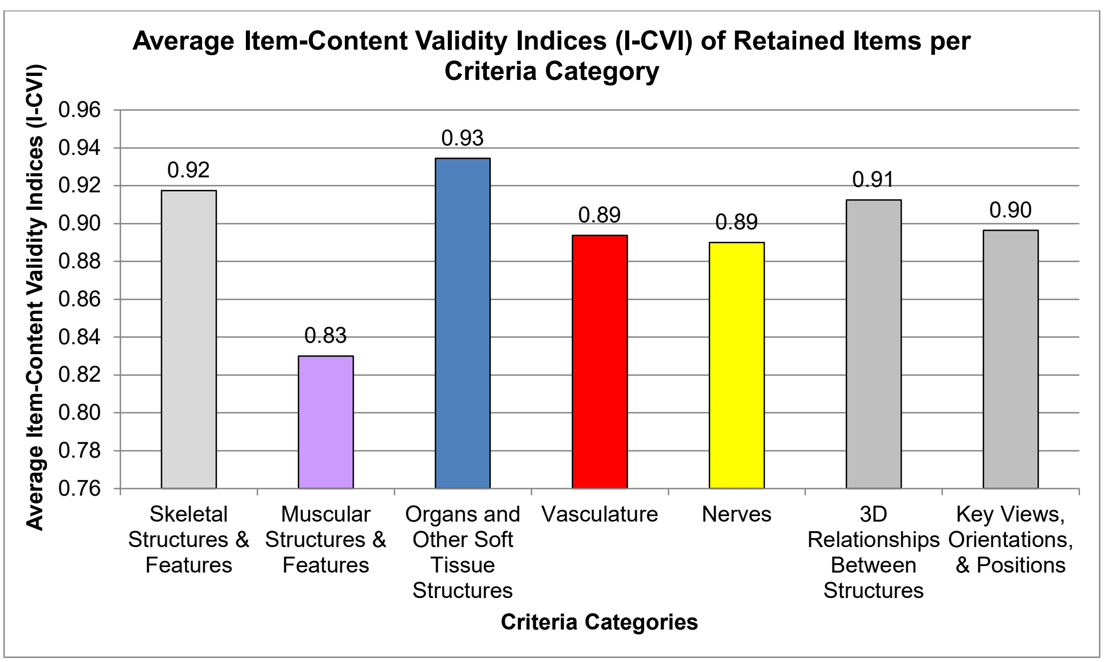

Figure 1. Average Item-Content Validity Index (I-CVI) Values for the Retained Items in the Final Criteria List. These average I-CVI values were calculated from the average all I-CVI values for items within each category in the final criteria list.

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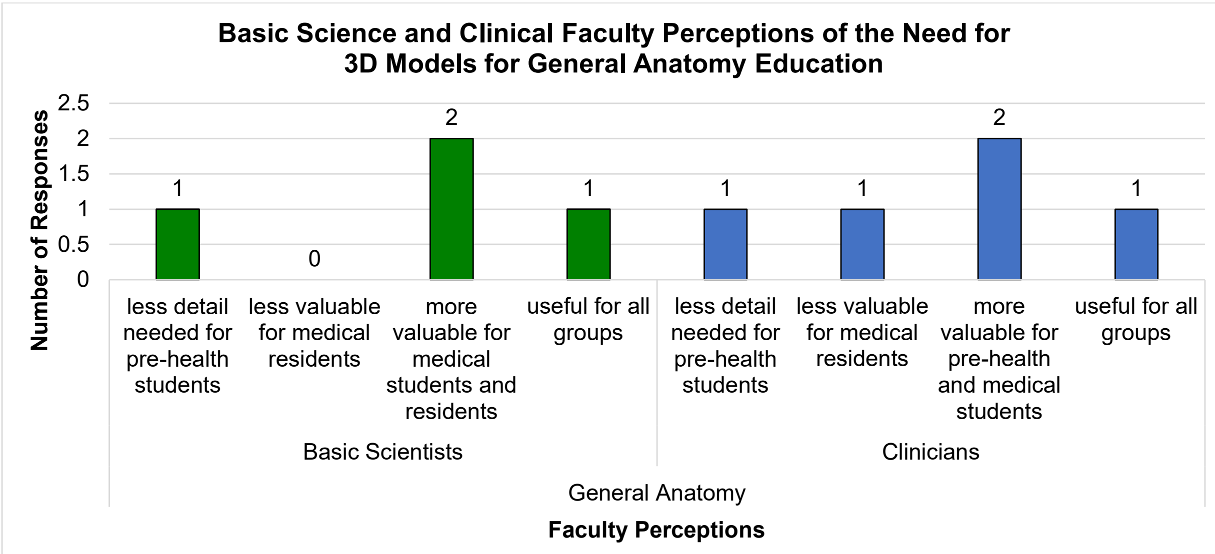

Figure 2. Faculty Perceptions of 3D Models in General Anatomy Education. Even though there are a total of 7 experts in this study, this graph shows a total of 9 responses (4 from basic science faculty and 5 from clinical faculty) because one scientist and one clinician provided two responses to the relevant survey question regarding their perception of the need for 3D models in teaching general anatomy to pre-health students, medical students, and medical residents. More basic scientists perceived general 3D anatomy to be more valuable for medical students and residents than pre-health students while more clinicians perceived general 3D anatomy to be more valuable for pre-health and medical students than medical residents.

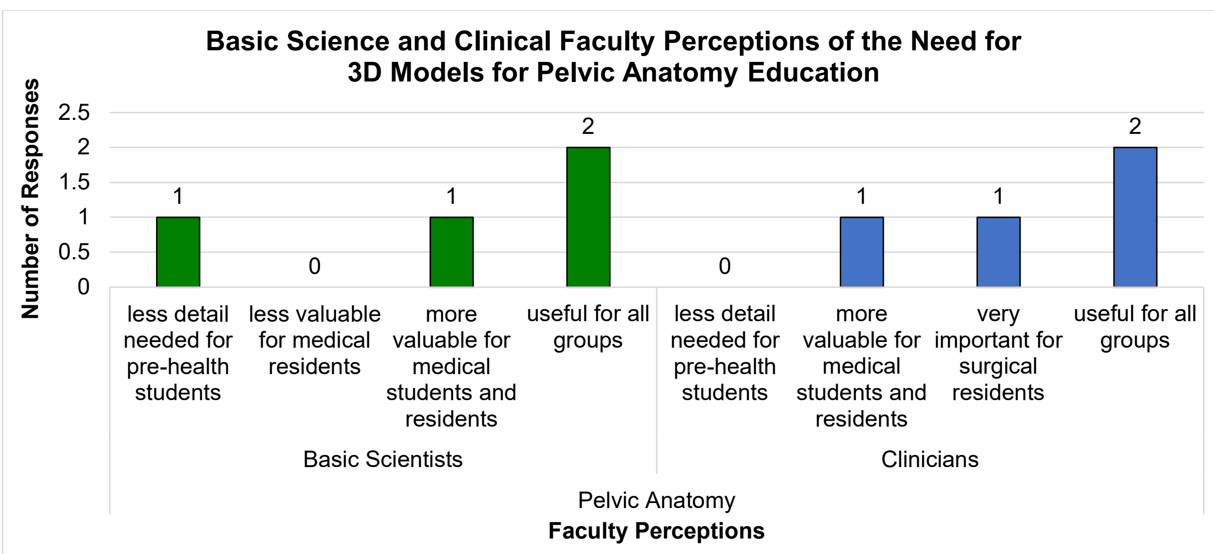

Figure 3. Faculty Perceptions of 3D Models in Pelvic Anatomy Education. Even though there are a total of 7 experts in this study, this graph shows a total of 8 responses (4 from basic science faculty and 4 from clinical faculty) because one clinician provided two responses to the relevant survey question regarding their perception of the need for 3D models in teaching pelvic anatomy to pre-health students, medical students, and medical residents. More basic scientists and more clinicians perceived pelvic 3D anatomy to be useful for all three learning groups.

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Table 1. The Number of Experts Solicited and Recruited for the Delphi Method.

Selection of Experts				
Expert Category	**Expert Discipline**	**# Solicited (n)**	**# Recruited (n)**	**# Dropped (n)**
Basic Scientists	Anatomy	5	3	0
Clinicians	Obstetrics and gynecology	11	1	0
	Pediatric urology	2	1	
	Urogynecology	1	1	0
	Urology	4	1	1 (after round 2)
	Total	**23**	**7**	**1**

This table displays the number of clinical and basic science experts who were solicited to participate in the study and the number of experts who submitted responses. Experts were solicited and recruited from faculty members in the anatomical sciences and from clinicians in the specialties or subspecialties of obstetrics and gynecology, pediatric urology, urogynecology, and urology. The urologist dropped out of the study, leaving a total of six experts to complete the study in full.

The following tables are available on the HAPS website HERE.

1. *Table 2: First generated list of expert responses (Delphi method rounds 1 and 2).*
2. *Table 3: Expert ratings and content validity indices (Delphi method round 3).*
3. *Table 4: Expert ratings and content validity indices (Delphi method round 4).*
4. *Table 5: A list of items that were not in agreement between rounds three and four.*
5. *Table 6: A list of items that were removed from the final criteria list.*
6. *Table 7: The final list of retained items and their content validity.*

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Table 8. Overall Internal Consistency Within Rounds 3 and 4.

Round	Total Number of Items (n)	Number of Items Excluded	Number of Valid Items	Overall Cronbach's Alpha Values
Round 3	159	23	136	0.970
Round 4	159	29	130	0.984

Coefficient Alpha values have the following reliability considerations:
>0.9 = excellent, >0.8 = good, >0.7 = acceptable, >0.6 = questionable, >0.5 = poor
(George and Mallery 2003).
The items which were excluded from the total number of items within each round were removed because one or more of the experts within each round did not provide a rating for the items on the four-point Likert-type scale.

Table 9. Item-Specific Internal Consistency Within Rounds 3 and 4.

Round	Item-Specific Cronbach's Alpha Values	Valid Item Numbers (based on Table 2)	Number of Valid Items (n)
Round 3	0.968	75, 76, 86, 100	4
	0.969	5, 17, 19-21, 30-33, 36-40, 42, 46, 47, 55, 58, 62, 65-70, 72, 77, 84, 95-97, 99, 110-117, 120-124, 129-133, 135, 136, 138, 139, 150, 152, 169-173	62
	0.970	7-9, 14, 24, 25, 28, 44, 49, 56, 64, 82, 87, 89-91, 98, 134, 137, 143-145, 149, 162, 165, 164, 168	27
	0.971	23, 27, 29, 41, 88	5
		Total →	98
Round 4	0.983	40, 46, 47, 49, 50-52, 55, 61, 65, 69-71, 74, 76, 80, 86, 99-104, 106, 113-115, 135-138, 140, 167	33
	0.984	5, 7-12, 17-21, 24-28, 30-33, 36-39, 41-45, 48, 59, 60, 64, 66-68, 73, 75, 77, 82-84, 87-91, 98, 105, 107, 110-112, 116, 117, 120-124, 130-134, 139, 143, 149, 152, 162, 166, 168, 169	74
	0.985	22, 23	2
		Total →	109

Coefficient Alpha values have the following reliability considerations:
>0.9 = excellent, >0.8 = good, >0.7 = acceptable, >0.6 = questionable, >0.5 = poor
(George and Mallery 2003).
The item numbers not present in the table represented those items which were excluded from the total number of items within each round because those items had zero variance, because one or more of the experts within each round did not provide a rating for the items on the four-point Likert-type scale, or because the item numbers represented the additional spaces provided in Table 2 for experts to write in items deemed missing from the scale.

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Table 10. Internal Consistency Between Experts' Ratings for Rounds 3 and 4.

Expert	Total Number of Items (n)	Number of Items Excluded	Number of Valid Items	Overall Cronbach's Alpha Values
Expert 1	159	22	137	0.917
Expert 2	159	4	155	**0.666**
Expert 3	159	18	141	0.832
Expert 4	159	3	156	0.740
Expert 5	159	4	155	**0.672**
Expert 6	159	26	133	0.856

Coefficient Alpha values have the following reliability considerations:
>0.9 = excellent, >0.8 = good, >0.7 = acceptable, >0.6 = questionable, >0.5 = poor
(George and Mallery 2003).
Coefficient Alpha values in red are considerably inconsistent with the other values.
Experts 1 through 3 include clinicians while experts 4 through 6 include basic scientists.

Participants

The participants in this study were experts, including faculty (physicians and scientists) who have proficiency pertaining to pelvic anatomy and who are involved in educating medical trainees on this anatomical region. These experts were selected, following specific guidelines, including the development of a list of disciplines pertinent to the study, the identification of personnel in those disciplines, the solicitation of those personnel to participate in the study, the classification of the personnel based on their qualifications, and the recruitment of the expert personnel in classification order (Okoli and Pawlowski 2004). The experts remained anonymous to one another throughout the entirety of the study. A total of 23 experts were recruited, and from this group a total of seven experts were elected to participate in the study. One expert dropped out of the study after the second round, leaving six experts to complete the study in full. While Okoli and Pawlowski (2004) suggested an expert pool of ten to eighteen individuals, Lynn (1986) suggested that an expert pool greater than ten was not necessary. The greater the number of experts, the greater the difficulty in establishing consensus among them. Table 1 provides details on the experts' respective disciplines. The protocol for this study was approved by the Institutional Review Board (IRB) of the University of Mississippi Medical Center (IRB # 2017-0220), and informed consent was obtained from all participants.

The Delphi Method

In the first round, experts in the Delphi panel were administered a list of free-response survey items. These items included questions inquiring about the experts' opinions on the use of 3D technology in teaching anatomy in general, and in teaching anatomy to pre-health students, medical students, and medical residents. Expert opinion was also sought in teaching the anatomy of the pelvis to the same three cohorts. Additionally, experts were asked for their opinion on what anatomical structures and three-dimensional relationships are most important to include in creating 3D models of the pelvis for the purpose of educating pre-health students, medical students, and medical residents. A few examples of these latter questions include the following items:

1. What anatomical structures, in your professional opinion, are most important to be included in a 3D anatomical model of the pelvis?
2. What 3D relationships among anatomical structures are most critical to portray to students and trainees through a 3D anatomical model of the pelvis?
3. Are there any key views, orientations, and/or positions of the anatomical structures within the pelvis that are vital for medical students to learn? If so, please describe them.

Several weeks before the questionnaires were distributed to the experts, three internal faculty members in the Clinical Anatomy Division reviewed the questions and provided their feedback, vetting the survey in its readiness for dissemination. One of the faculty reviewers later also served as an expert on the Delphi panel, but this individual was not aware of potential recruitment and selection as an expert for this study during the questionnaire review process. After the questionnaires were distributed to the experts, the experts' opinions were solicited using both email and in-person formats. The interviews were recorded manually on paper copies of the questionnaire and transcribed electronically.

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In the second round, the transcriptions from the personal and phone interviews were submitted to each corresponding interviewee via email communications to confirm their responses from the first round. However, expert respondents who chose to submit their responses to the survey in round one via email were able to forego the second round since there was no need to confirm the validity of their direct written replies. Each set of revised transcriptions and first-round email submissions were then analyzed. All nonrepeating anatomical structures, 3D relationships, and key views, orientations, and positions were included in a generated list of tentative pelvic criteria. This generated list is provided in Table 2.

In the third round, this generated list was sent to all of the experts via email or was administered in the form of in-person or phone interviews. To determine content validity, these items were rated using a four-point Likert-type scale similar to the one described by Davis (1992) and often used in the literature. In this particular scale, 1 = not important, 2 = somewhat important, 3 = quite important, and 4 = highly important. The experts were asked to review each potential item in the list and rate the importance of each item in medical training using the four-point Likert-type scale. Experts were also requested to provide a justification for each rating.

In the fourth round, the same list of items were rated once again by all experts at least one week later to confirm their original rankings, and the experts were allowed to offer additional feedback as well as additional items to be included in the list of criteria. The provision of the opportunity to include additional criterion items is similar to a procedural step used in the study by Lisk *et al.* (2014). The experts used the identical procedure followed in round three for reliability purposes.

In addition, the experts were asked an additional five questions about their views of the overall Delphi method and its use in gathering experts' opinions in general, in regards to anatomy, and in regards to pelvic anatomy specifically. Initially, these questions were intended to be asked of all experts in a group setting as a focus group session. However, due to scheduling conflicts between each of the experts, these questions were included at the end of the second generated list distributed during the fourth round.

Data Analysis

During rounds three and four, those items which were rated as a three or a four by the majority of experts were retained in the instrument. Responses were used to calculate a content validity index (CVI) and determine whether an item would be retained. The CVI for each item, also known as the item-level content validity index (I-CVI) is the proportion of experts who rate the item as 3 or 4 (important) versus 1 or 2 (not important). As recommended in the literature (Davis 1992), items with I-CVI's that were less than 0.80 were dropped from the evaluation tool. The CVI for the entire set of items, also known as the scale-level content validity index (S-CVI), was also calculated by determining the mean proportion of items rated as a three or a four by the recruited experts. This particular form of S-CVI is also called the average calculation method (S-CVI/Ave). To maintain the rigor of the instrument, the minimum S-CVI/Ave for the instrument was established as 0.90 as recommended by the literature (Waltz *et al.* 2005, Polit and Beck 2006). Therefore, any S-CVI/Ave calculation below 0.90 would have warranted further analysis of rounds three and four.

For both the third and fourth rounds, the internal consistency via Cronbach's alpha was calculated for each item, for the entire scale, and for the experts' ratings between the third and fourth rounds using SPSS 20.0.

Results

Delphi Method: Rounds 1 and 2

Of the seven experts recruited in this study, three agreed to participate in round one via interviews. The pediatric urologist and the urogynecologist participated in the in-person interviews while the other urologist participated in a phone interview. The experts reviewed their transcribed responses in a second round and confirmed their responses with only minor corrections via email. The other four experts, who included a gynecologist and three basic science faculty members in anatomy, submitted their first-round responses via email.

From the responses of these seven experts, a list of 156 items was generated. The items included anatomical structures and features, 3D relationships among structures, and key views, orientations, and positions. Overall, the list contained 111 anatomical structures and features, 19 3D relationships between structures, and 26 key views, orientations, and positions. The anatomical structures and features included 33 skeletal structures and features, 14 muscular structures and features, 38 organs and other soft tissue structures (12 male-specific, 14 female-specific, 17 non-sex-specific structures), 13 vascular structures, 8 nerves, and 5 spaces (Table 2).

Delphi Method: Round 3

In round three, all 156 items were rated by six of the experts on a four-point Likert-type scale. The urologist dropped out of the study. Table 3 displays the ratings for each item by each of the experts along with its respective I-CVI. It also provides the S-CVI/Ave for the entire scale (0.79).

Delphi Method: Round 4

All 156 items from the third round were rated again by six of the experts. The only change made to the list was the addition of the individual abdominal wall muscles rather than simply grouping them as abdominal wall muscles, bringing the total number of criteria to 159. Each of these muscles was then

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rated as a separate item. Table 4 displays the ratings for each item by each of the experts along with its respective I-CVI. It also provides the S-CVI/Ave for the entire scale (0.79).

Overall Content Validity

In the third and fourth rounds, the I-CVI values were in agreement for 136 of the 159 items, warranting either inclusion in or removal from the criteria list. For the remaining 23 items, the I-CVI values were not in agreement. These items had third- and fourth-round values whereby the former either warranted the removal of the items from the list or warranted the retention of the items in the list. Averages of these I-CVI values were calculated, providing I-CVI values that warranted the removal of 19 of the 23 items from the list of criteria. Four items were retained as their average I-CVI values were 0.83. Table 5 provides a list of those 23 items not in agreement between the third and fourth rounds, their third- and fourth-round I-CVI values, and their average I-CVI values. In addition to these 23 items, 39 more items were removed from the criteria list because they had I-CVI values below 0.80 in both the third and fourth rounds. Table 6 provides a list of all 62 items that were removed from the criteria list overall, their third- and fourth-round I-CVI values, and their average I-CVI values. Table 7 provides the final list of retained criteria with their third- and fourth-round I-CVI values and their average I-CVI values. After the removal of all 62 items, the final list of retained criteria contained a total of 97 items with an S-CVI/Ave value of 0.92. Figure 1 provides a graphical representation of the average I-CVI values for the items within each category of the final criteria list.

Internal Consistency

Coefficient Alpha supported rater consistency between rounds 3 and 4. These results are presented in Table 8. Criteria items that were retained in the reliability analysis met a certain threshold suggesting that they were consistent across items. All of the retained items had a Coefficient Alpha above 0.90, which according to George and Mallery (2003) indicates excellent internal consistency. These results are presented in Table 9. The Coefficient Alpha results in Table 10 showed two expert raters who rated items differently from the other four experts. One expert was a clinician, and one was a basic scientist. According to George and Mallery (2003), Coefficient Alpha values as low as 0.7 are acceptable while values between 0.70 and 0.60 are questionable. Although Nunnally (1967) stated that coefficient values of 0.60 or 0.50 were sufficient in "early stages of research," he increased the coefficient value to 0.70 in a later edition (Nunnally 1978).

Experts' Perceptions

Overall, participants found the Delphi method to be an effective technique for gathering experts' opinions. Although several experts found the multiple rounds to be repetitive, redundant, and tedious, all of the experts deemed it to be efficient. In addition, one expert in particular admitted to being unaware of another less time-consuming method to acquire experts' opinions.

Another expert made a fair point that the specific needs of the individual learning cohorts have considerable variation. These learning groups include graduate- and undergraduate-level medical, dental, kinesiology, and other allied health students as well as undergraduate anatomy and physiology students. This expert continued to say that "a robust program can be tailored to the group" based on the anatomical knowledge they are expected to learn. This specific study did not ask experts to provide pelvic criteria important specifically for certain cohorts of students, but it did ask the experts to consider criteria important for a 3D anatomical model of the pelvis, in general. However, experts were asked to provide criteria "most critical to portray" to anatomy students and trainees regarding 3D relationships among anatomical structures. These anatomy students include graduate- and undergraduate-level medical, dental, kinesiology, and other allied health students as well as undergraduate anatomy and physiology students.

In addition, during the first-round survey, experts were asked questions regarding their perception of the need for 3D anatomy in general anatomy education as well as the need for 3D anatomy in pelvic anatomy education, specifically for pre-health students, medical students, and medical residents. Overall, there were mixed responses from the experts in terms of their views on which form of 3D anatomy education was more or less valuable for these particular cohorts of students and trainees. However, the responses, according to Figure 2, suggest that two of the three basic science experts viewed general 3D anatomy to be more valuable for medical students and medical residents than pre-health students while two of the four clinical experts viewed general 3D anatomy to be more valuable for pre-health and medical students than medical residents. In turn, the responses, according to Figure 3, suggest that two of the three basic science experts and two of the four clinical experts viewed pelvic 3D anatomy to be useful for all three learning groups.

Discussion

Validity

Validity is an important concept to be considered in the development of standardized instruments and tools that will serve a purpose in teaching and training individuals in a particular field or discipline. In addition, the techniques used to validate these instruments and tools must also be validated using methodical, well-documented procedures. Therefore, measures were taken to validate each round of the Delphi process. Hasson and Keeney (2011) mention several different types of validity that were considered in the process of validating the Delphi method.

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During round one as well as all three additional rounds of the Delphi method, the expert participants remained anonymous to each other in order to prevent experts from influencing the responses of one another, thus helping to maintain the criterion-related validity (Hasson and Keeney 2011). According to both Schmidt (1997) and Okoli and Pawlowski (2004), in the second round, experts should review their first-round responses as interpreted and organized by the investigator to approve or revise them as necessary in order to maintain the construct validity (Hasson and Keeney 2011) of the instrument being produced. Although this particular round was necessary only for the expert responses acquired via personal or in-phone interviews, it ensured that the criteria recorded from the experts during their first-round interviews were indeed the criteria they intended to profess to the interviewee.

Despite the fact that one expert dropped out of the study, a total of six experts were deemed sufficient because, according to Lynn (1986), I-CVI values as low as 0.78 are acceptable when there are six or more experts. In consideration of content validity, the average calculation method for scale content validity (S-CVI/Ave) was used because it is not quite as stringent as the universal agreement calculation method (S-CVI/UA) which is the proportion of items that received a rating of 3 or 4 from all of the experts. The average calculation method was used since the probability of reaching one hundred percent agreement among experts decreases as the number of consulted experts increases (Polit and Beck 2006). Since the S-CVI/Ave of the final list of criteria was greater than 0.90, the overall content of the list is rigorously valid (Waltz *et al.* 2005, Polit and Beck 2006).

A four-point Likert-type scale, instead of a traditional five-point Likert scale, was used to determine content validity in order to ensure that experts made a definitive decision about whether an item was or was not important. Similar four-point scales have been used in other studies (Waltz and Bausell 1981, Lynn 1986, Davis 1992). In fact, one study in particular argued the use of a four-point scale to deter experts from settling on irresolute ratings (Lynn 1986). In this particular study, the ultimate goal was to establish consensus among the experts involved as to which items are truly important to consider in pelvic models.

Reliability

This fourth administration of the Delphi method allowed for a test-retest measure for ascertaining whether the same group of experts can come to a consensus at a different time frame similar to a study performed by Uhl (1975) who found that consensus was obtained in three rounds of Delphi administration. Such consensus established over multiple time periods corroborates the test retest reliability of the Delphi process.

For this reason, items with an I-CVI less than 0.80 in the third round were not immediately removed from the overall list of criteria before the second rating as they were in the Lisk *et al.* study (2014). The experts were allowed to rerate all of the original criterion items again in the fourth round at least one week after the third round.

Internal Consistency

In the third round, each of the following component items (as they were numbered in Table 2) had zero variance, and they were removed from the scale in regards to reliability measurements: 1, 2, 3, 4, 6, 10, 11, 12, 13, 15, 16, 18, 22, 26, 57, 63, 78, 79, 85, 92, 148, 153, and 154. In the fourth round, each of the following component items (as they were numbered in Table 2) had zero variance, and they were removed from the scale in regards to reliability measurements: 1, 2, 3, 4, 6, 13, 14, 15, 16, 56, 57, 58, 62, 63, 72, 78, 79, 85, 92, 95, 96, 97, 144, 145, 153, 155, 170, 171, and 172. The determinant of the covariance matrix in both the third and fourth rounds was zero or approximately zero. Statistics based on its inverse matrix could not be computed, and they were displayed as system missing values.

Coefficient Alpha is a single measure of internal consistency. Just because an item may not be consistent with other items does not mean it cannot be considered. Coefficient Alpha can also be thought of as measuring unidimensionality. Perhaps those items that were inconsistent were just as important, but they referenced another dimension. The inconsistency between expert number two and expert number five could potentially be due to differing areas of expertise or different views on items that are most important. Further exploration would require a detailed factor analysis.

Experts' Perceptions

Overall, there were mixed perceptions of basic science and clinical faculty regarding the value of general and pelvic 3D anatomy for pre-health students, medical students, and medical residents according to Figure 2. The fact that 67% (two out of three) basic science experts viewed general 3D anatomy to be more valuable for medical students and residents than for pre-health students could have been because basic science faculty consider that pre-health students require less detail in general 3D anatomical knowledge in their earlier years of anatomy instruction. In fact, one of the faculty members with such a view felt that pre-health students needed less detail in general 3D anatomical knowledge than medical students and medical residents.

Fifty percent (two out of four) of the clinical experts might have viewed general 3D anatomy to be more valuable for pre-health and medical students than medical residents because these experts acknowledged the fact that pre-health students benefit from learning from models before learning

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from real human anatomy. Moreover, one of the clinical experts stated that while 3D anatomy is initially important for medical residents' surgical training in the form of simulations, eventually they will be performing surgeries on real people and will have less need for 3D simulations. Nevertheless, one clinician emphasized the fact that training medical residents on surgical simulations before performing surgical procedures on real patients is critical to preventing injuries to patients.

On the other hand, the majority of experts viewed pelvic 3D anatomy to be important for pre-health students, medical students, and medical residents, according to Figure 3. The fact that that 67% of the basic science experts and 50% of the clinical experts viewed pelvic 3D anatomy to be useful for all three learning groups might have been because all of these experts understood that the pelvic region is an anatomical area of high complexity and limited accessibility. In fact, most of these experts stated this view explicitly in their responses. Since 3D pelvic models typically reduce the congestion of fascia and adipose tissue that are visible in cadavers, they can potentially reduce the cognitive load of students and trainees when they are learning the 3D relationships.

The Development of the Pelvic Criteria List

Removed items

Most of the anatomical structures that were removed from the initial generated list of pelvic criteria at the end of the third and fourth rounds collectively were soft tissue structures that cannot be readily viewed using computerized tomographic (CT) imaging and that have relatively little clinical importance. Work is already in progress by the authors in reconstructing a model of the male pelvis from CT scans using Amira® software. Thus, this valid list of criteria will help ensure that only those anatomical structures which are truly important for students and residents to learn will be included in completed pelvic models.

Most of the removed anatomical structures included ligaments, fascial tissue, relatively obscure organs, veins, and smaller, less significant nerves. However, some of the structures that were removed based on the overall experts' opinions were surprising. For instance, the Fallopian tubes (oviducts) as anatomical structures were ultimately removed from the list, but basic science and clinical experts in the third and fourth rounds asserted their importance in understanding their relationships to the ovaries, uterine wall, and vasculature and in understanding gynecological surgical landmarks, respectively. In addition, the obturator nerve was deemed important by basic science and clinical experts as it is a common source of iatrogenic injury due to misrecognition during surgical procedures. In fact, obturator nerves are typically at risk during lymphadenectomy for endoscopic radical prostatectomy procedures (Stolzenberg *et al.* 2016, Teber *et al.* 2009) which are very common urological surgeries. Nevertheless, an important consideration to keep in mind is the fact that not all anatomy learners intend to pursue clinical practice in a healthcare field. Many anatomy students throughout the world take anatomy and physiology, and the students within this particular cohort who have no intention of becoming physicians, dentists, or other allied health professionals may only need to know prominent anatomical structures that provide them with a basic context of an anatomical region as complex as the pelvis.

Moreover, some structures, despite their clinical importance, were removed because they are not easily distinguished on CT scans, they consist of different component structures by a another name, they are not important surgical landmarks in the experts' respective disciplines, or they can be easily viewed and appreciated in other learning formats such as traditional two-dimensional (2D) images from textbooks. For example, the piriformis muscle was ultimately removed because the gynecological expert claimed that it is poorly differentiated on CT scans although overall muscle groups can be visualized and because one of the urologists claimed that it was not an important urological surgical landmark. Nevertheless, all of the basic scientists asserted its importance; one of them even reasoned that it was critical for understanding 3D relationships. Clinically, knowing the location of the piriformis muscle in relation to the sciatic nerve is also important for understanding the connection between piriformis syndrome and sciatica (Hopayian *et al.* 2010).

Some of the structures, such as the perineal body, external urethral sphincter muscle, and abdominal wall muscles, were removed from the criteria list due to their low item-level content validity index (I-CVI) values (less than 0.80). However, all of the clinicians considered these structures to be important surgical landmarks or important urological surgical structures. Some basic science faculty might have viewed these structures with less importance probably because they do not encase the pelvic cavity, or they are difficult to distinguish in CT scans. Although these structures were important for urologists or gynecologists, not all anatomy students will become surgeons or urologists. The majority of anatomy students may only need a basic overview of anatomical structures within the pelvis region as suggested by some of the experts' comments from the first-round survey.

Finally, some items which were removed from the criteria list, despite their clinical importance, will still be potentially present in a pelvis model constructed from CT scans. For instance, the five spaces that have surgical relevance might be visualized as much less attenuated regions in a pelvis model if the boundaries created by the surrounding soft tissue structures are also visualized.

Retained Items

Interestingly, several trends in terms of what basic scientists viewed as important as opposed to what clinicians viewed as important arose from the experts' ratings. One major trend

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that arose from the data in Tables 3 and 4 suggested that those items that clinicians, but not basic scientists, rated highly were important surgical structures or landmarks. Another trend from these tables seemed to suggest that those items which basic scientists, but not clinicians, rated highly were important for teaching anatomy students the 3D relationships of anatomical structures to each other in the pelvic region. On average, however, both basic science and clinical experts, according to Figure 1, tended to rate most of the skeletal structures and features as well as most of the organs and other soft tissues structures as important.

The Importance of Virtual 3D Anatomy

Historically, cadaveric dissection has been the traditional method by which students have learned human anatomy. One study in particular has shown that cadaveric dissection is the best way for students to learn the 3D relationships of anatomical structures (Wright 2012, Bergman *et al.* 2015). The use of prosections is also growing in popularity and effectiveness in conveying these 3D concepts to students (Nnodim 1990, Samarakoon *et al.* 2016). However, cadaveric dissections and prosections are not always as effective in helping students understand the 3D relationships of anatomical structures in regions of high complexity and limited accessibility.

Since some undergraduate institutions, especially, do not have access to cadavers due to finances or ethical matters (Robbins *et al.* 2009, Lempp 2005), there is a need for research to confirm what types of 3D technology and which specific virtual 3D models are efficient to use in the instruction of anatomy students. Therefore, methodical procedures for valid and reliable instrument construction for virtual 3D model assessment need to be followed to ensure the creation of valid virtual 3D models of anatomical regions such as the pelvis.

Conclusions

Overall, a valid and reliable list of pelvic criteria was successfully created using a multiple-round Delphi method procedure. Although the removal of some items from the criteria list was surprising, one expert suggested that virtual 3D anatomical models can be customized for different groups of anatomy learners. Moreover, all of the experts viewed the Delphi method process to be an effective way of gathering experts' opinions.

Limitations

First of all, participants in a multiple-round Delphi method study might have found the repetitious or redundant nature of the iterative rounds and questions to be annoying. In addition, participants might have also considered the multiple rounds to be time consuming and even unnecessary, especially the third and fourth rounds since they accomplished the same goal of establishing consensus among experts. However, the duplication of these two rounds was necessary to ensure test-retest reliability of the instrument. Nevertheless, these first two limitations might have been regarded as sufficient reason for participants to discontinue their participation in the study, thus compelling participants to drop out. In fact, in this study, one of the experts dropped out, thus hindering the overall content validity of the criteria list. However, the I-CVI/Ave was still calculated at a rigorously valid value.

Moreover, experts who submitted their responses electronically for both the third and fourth rounds could have easily duplicated or copied their responses from previous iterations of the instrument. Such actions could have potentially biased the validity of the overall instrument. However, in this study, no ratings between the two rounds for any of the experts were completely identical. In fact, several experts submitted their third- and fourth-round responses in different formats.

Furthermore, while the Delphi method was useful for collecting experts' opinions about anatomy in general, soliciting opinions from experts regarding complex regions of anatomy such as the pelvis was more problematic. Securing adequate numbers of experts proved to be a challenge, given the varied locations of experts, their varying time availability to commit to participation, and their potential need for incentives. Fortunately, a range of three to ten experts was deemed sufficient for a Delphi method procedure (Lynn 1986). Plus, ensuring that participants were willing to complete all phases of the survey proved to be difficult, especially since experts were located at a distance from the study director.

Future Directions

Future directions will include the use of this valid list of criteria to inform the addition of anatomical structures to an existing virtual 3D model of the male pelvis and to validate the male pelvis model once it is completed. Additional future studies will focus on the impact of the validated virtual 3D male pelvis model on learning and retention in anatomical studies. This list of criteria could also be used by researchers to validate any virtual 3D anatomical pelvis model that already exists. By using the criteria list to validate current pelvis models, researchers can ensure that the models are accurate before implementing them in student instruction. Further exploration might also involve modifying validated models to tailor them to specific target groups of learners. Modifications could be made by consulting experts who have a basic understanding of the target learners' baseline knowledge at the beginning of their respective educational program, who have routine interactions with the learners, and who have experience teaching or training them.

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Literature cited

Azer SA, Azer S (2016) 3D anatomy models and impact on learning: A review of the quality of the literature. *Health Professions Education*. 2: 80-98. doi: 10.1016/j.hpe.2016.05.002

Bergman EM, de Bruin ABH, Vorstenbosch MATM (2015) Effects of learning content in context on knowledge acquisition and recall: A pretest-posttest control group design. *BMC Med. Educ.* 15: 133. doi: 10.1186/s12909-015-0416-0

Beyersdorff D, Schiemann T, Taupitz M, Kooijman H, Hamm B, Nicholas V (2001) Sectional depiction of the pelvic floor by CT, MR imaging and sheet plastination: Computer-aided correlation and 3D model. *Eur. Radiol.* 11: 659-664. doi: 10.1007/s003300000561

Brown PM, Hamilton NM, Denison AR (2012) A novel 3D stereoscopic anatomy tutorial. *Clin. Teach.* 9: 50-53. doi: 10.1111/j.1743-498X.2011.00488.x

Caves R (1988) Consultative methods of extracting expert knowledge about clinical competence. In: R. Ellis (Ed.) Professional Competence and Quality Assurance in the Caring Professions (pp. 199-299). London, UK: Chapman Hall.

Cui D, Wilson TD, Rockhold RW, Lehman MN, Lynch JC (2017) Evaluation of the effectiveness of 3D vascular stereoscopic models in anatomy instruction for first year medical students. *Anat. Sci Educ.* 10: 34-45. doi: 10.1002/ase.1626

Dalkey NC, Helmer O (1963) An experimental application of the Delphi method to the use of experts. *Management Science.* 9: 458-467. doi: 10.1287/mnsc.9.3.458

Davis LL (1992) Instrument review: Getting the most from a panel of experts. *Applied Nursing Research.* 5: 194-197. doi: 10.1016/S0897-1897(05)80008-4

George D, Mallery P (2003) SPSS for Windows Step by Step: A Simple Guide and Reference. 11.0 Update (Fourth Edition). Boston, MA: Allyn & Bacon.

Hasson F, Keeney S (2011) Enhancing rigour in the Delphi technique research. *Technological Forecasting & Social Change.* 78: 1695-1704. doi: 10.1016/j.techfore.2011.04.005

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Helmer O (1967) Systematic Use of Expert Opinions (Document Number P-3721). Santa Monica, CA: The RAND Corporation.

Hisley KC, Anderson LD, Smith SE, Kavic SM, Tracy JK (2008) Coupled physical and digital cadaver dissection followed by a visual test protocol provides insights into the nature of anatomical knowledge and its evaluation. *Anat. Sci. Educ.* 1: 27-40. doi: 10.1002/ase.4

Hopayian K, Song F, Riera R, Sambandan S (2010) The clinical features of the piriformis syndrome: A systematic review. *Eur. Spine J.* 19:2095-2109. doi: 10.1007/s00586-010-1504-9

Hoyek N, Collet C, Di Rienzo F, De Almeida M, Guillot A (2014) Effectiveness of three-dimensional digital animation in teaching human anatomy in authentic classroom context. *Anat. Sci. Educ.* 7: 430-437. doi: 10.1002/ase.1446

Khot Z, Quinlan K, Norman GR, Wainman B (2013) The relative effectiveness of computer-based and traditional resources for education in anatomy. *Anat. Sci. Educ.* 6: 211-215. doi: 10.1002/ase.1355

Lawshe CH (1975) A quantitative approach to content validity. *Personnel Psychology.* 28: 563-575. doi: 10.1111/j.1744-6570.1975.tb01393.x

Lempp HK (2005) Perceptions of dissection by students in one medical school: Beyond learning about anatomy. A qualitative study. *Anatomy Teacher*. 39: 318-325. doi: 10.1111/j.1365-2929.2005.02095.x

Lisk K, Flannery JF, Loh EY, Richardson D, Agur AMR, Woods NN (2014) Determination of clinically relevant content for a musculoskeletal anatomy curriculum for physical medicine and rehabilitation residents. *Anat. Sci. Educ.* 7: 135-143. doi: 10.1002/ase.1393

Lynn MR (1986) Determination and quantification of content validity. *Nursing Research*. 35: 382-386. doi: 10.1097/00006199-198611000-00017

Maggio MP, Hariton-Gross K, Gluch J (2012) The use of independent, interactive media for education in dental morphology. *J. Dent. Educ.* 76: 1497-1511.

Marsh KR, Griffin BF, Lowrie Jr. DJ (2008) Medical student retention of embryonic development: Impact of the dimensions added by multimedia tutorials. *Anat. Sci. Educ.* 1: 252-257. doi: 10.1002/ase.56

Müller-Stich BP, Löb N, Wald D, Bruckner T, Hans-Peter M, Kadmon M, Büchler MW, Fischer L (2013) Regular three-dimensional presentations improve in the identification of surgical liver anatomy—A randomized study. *Anat. Sci. Educ. BMC Med. Educ.* 13: 131. doi: 10.1186/1472-6920-13-131

Nicholson DT, Chalk C, Funnell WR, Daniel SJ (2006) Can virtual reality improve anatomy education? A randomized controlled study of a computer-generated three-dimensional anatomical ear model. *Med. Educ.* 40: 1081-1087. doi: 10.1111/j.1365-2929.2006.02611.x

Nnodim JO (1990) Learning human anatomy: By dissection or from prosections? *Med. Educ.* 24: 389-395. doi: 10.1111/j.1365-2923.1990.tb02456.x

Nunnally JC (1967) Psychometric Theory. New York, NY: McGraw-Hill.

Nunnally JC (1978) Psychometric Theory (Second Edition). New York, NY: McGraw-Hill.

Okoli C, Pawlowski SD (2004) The Delphi method as a research tool: An example, design considerations, and applications. *Information & Management*. 42: 15-29. doi: 10.1016/j.im.2003.11.002

Parikh M, Rasmussen M, Brubaker L, Salomon C, Sakamoto K, Evenhouse R, Ai Z, Damaser MS (2004) Three dimensional virtual reality model of the normal female pelvic floor. *Ann. Biomed. Eng.* 32: 292-296. doi: 10.1023/B:ABME.0000012749.79488.d6

Polit DF, Beck CT (2006) The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Research in Nursing & Health.* 29: 489-497. doi: 10.1002/nur.20147

Qayumi AK, Kurihara Y, Imai M, Pachev G, Seo H, Hoshino Y, Cheifetz R, Matsuura K, Momoi M, Saleem M, Lara-Guerra H, Miki Y, Kariya Y (2004) Comparison of computer-assisted instruction (CAI) versus traditional textbook methods for training in abdominal examination (Japanese experience). *Med. Educ.* 38: 1080-1088. doi: 10.1111/j.1365-2929.2004.01957.x

Robbins BD, Tomaka A, Patterson CIJ, Styn G (2009) Lessons from the dead: The experiences of undergraduates working with cadavers. *OMEGA – Journal of Death and Dying.* 58: 177-192. doi: 10.2190/OM.58.3.b

Samarakoon LB, Vithoosan S, Kokulan S, Dissanayake MM, Anthony DJ, Dissanayake V, Jayasekara R (2016) Anatomy of teaching anatomy: Do prosected cross sections improve students understanding of spatial and radiological anatomy? *Anatomy Research International.* Article ID 8984704, 4 pages. doi: 10.1155/2016/8984704

Sergovich A, Johnson M, Wilson TD (2010) Explorable three-dimensional digital model of the female pelvis, pelvic contents, and perineum for anatomical education. *Anat. Sci. Educ.* 3: 127-133. doi: 10.1002/ase.135.

Schmidt RC (1997) Managing Delphi surveys using nonparametric statistical techniques. *Decision Sciences.* 28: 763-774. doi: 10.1111/j.1540-5915.1997.tb01330.x

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Stolzenburg JU, Rabenatt R, Do M, Lee B, Truss MC, McNeil A, Burchardt M, Jonas U, Liatsikos E (2016) Complications of endoscopic extraperitoneal radical prostatectomy (EERPE): Prevention and management. *World J. Urol.* 24: 668-675. doi: 10.1007/s00345-006-0133-8

Teber D, Gozen AS, Cresswell J, Canda AE, Yencilek F, Rassweiler J (2009) Prevention and management of ureteral injuries occurring during laparascopic radical prostatectomy: The heilbrohm experience and a review of the literature. *World J. Urol.* 27: 613-618. doi: 10.1007/s00345-009-0428-7

Uhl NP (1975) Consensus and the Delphi process. Paper presented at the Annual Meeting of the American Educational Research Association (Washington, D. C., April 1975) (ERIC Document) ED 104201.

Waltz CF, Bausell RB (1981) Nursing Research: Design, Statistics, and Computer Analysis. Philadelphia, PA: F. A. Davis.

Waltz CF, Strickland OL, Lenz ER (2005) Measurement in Nursing and Health Research (Third Edition). New York, NY: Springer Publishing Co.

Womble MD (1999) Anatomy and computers: A new twist to teaching the oldest medical course. *Bioscene*. 25: 15-17.

Wright SJ (2012) Student perceptions of an upper-level, undergraduate human anatomy laboratory course without cadavers. *Anat. Sci. Educ.* 5: 146-157. doi: 10.1002/ase.1265

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The Impact of Face-to-Face Exam Viewing on Future Exam Performance in a First Term Anatomy and Physiology Course

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Abstract
The purpose of this investigation was to determine if attending a face-to-face midterm exam review with the instructor predicts final exam performance in an Anatomy and Physiology I course. Students were invited to attend office hours in small groups to review their midterm exams. Multiple linear regression was used to test whether attendance at an exam review appointment, midterm exam score, and/or high school grade point average (GPA) significantly predicted the final exam score. Alpha levels were set *a priori* to $p<.05$. Attendance at an exam review appointment and high school GPA significantly predicted final exam grades (Beta =.081, p=.042; Beta =.126, p=.002, respectively) but midterm exam scores explained most of the model variance in final exam scores (Beta =. 736, $p<.000$). Taken together, the three predictors in the model explained 58% of the variance in final exam scores (adjusted R^2=.58). The results of this study suggest that exam review appointments should be continued but enhanced to include a more structured analysis of the midterm exam. Follow up with students on the implementation of new study strategies should occur prior to the final exam.
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Key words: anatomy, physiology, examinations, face-to-face exam review, evaluation

Introduction
Anatomy and Physiology is a foundational course series for most health-related professions. A number of researchers have attempted to identify factors that predict performance in Anatomy and Physiology courses. High school grade point average (GPA) has been a consistent predictor of grades in Anatomy and Physiology (Anderton *et al.* 2016, Gultice *et al.* 2015, Rompolski *et al.* 2016, Sturges *et al.* 2016). However, success in high school biology and chemistry courses may be even more predictive of success in Anatomy and Physiology than high school GPA (Gultice *et al*. 2015). The number of credit hours carried at the time of entry into anatomy and physiology has also been positively associated with performance in anatomy and physiology (Gultice *et al.* 2015, Russel *et al.* 2016). Performance may also be influenced by the age and maturity of students and whether or not they have previously taken other college science courses such as biology or chemistry (Rompolski *et al.* 2016, Russel *et al.* 2016). Finally, a student's chosen major predicts final grades in anatomy and physiology (Anderton *et al.* 2016, Rompolski *et al.* 2016, Schutte 2016).

In a study by Gultice *et al.* (2015), a regression model was created to predict success in Anatomy and Physiology I. The model included age, total credit hours earned in college, current credit load for the semester and high school GPA (Gultice *et al.* 2015). This model explained 81% of the variance in the final grade in Anatomy and Physiology I. Identifying students at risk for not receiving passing grades in anatomy and physiology courses is worthwhile. However, a plan of action to assist the students who are likely to struggle is needed and is understudied. Students often underestimate the effort that learning anatomy and physiology will require and overestimate the grades they expect to achieve (Eagleton 2015, Schutte 2016, Sturges *et al.* 2016). In anatomy and physiology courses that offer only two examinations, such as a midterm exam and a final exam, students may not have a reasonable or clear understanding of where they stand in the course until the coursework is over 50% complete.

The first exam in anatomy and physiology, possibly the midterm exam, can provide an opportunity for students to reflect on their learning strategies and make adjustments. This can be accomplished during exam review sessions with the instructor. Research examining the frequency, structure, and outcomes of reviewing examinations with students is limited. This suggests that the decision of if, or how, to review exams with students is largely at the discretion and preference of each instructor. Some instructors may hand exams back to students, but this may increase the possibility of exams being disseminated to future students or require faculty to consistently make new exams. The exam can be reviewed in class, but this may take up necessary class time. Without reviewing exams, students who performed poorly may move forward with the same strategies and receive the same results (Wiles, 2015).

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Students may choose to attend office hours or request an appointment with the instructor to discuss their performance on an exam. However, research suggests that office hours are very poorly utilized by students (Griffin *et. al* 2014, Guerrero and Rod 2013). Griffin *et al.* (2014) sought to find out why students do not attend office hours, and if any of these reasons were within the instructor's control. Six hundred twenty-five students were surveyed across all four years of their academic study. Sixty-six percent of students surveyed reported never using office hours; and, only 8% reported using them for two or more sessions. The perceived convenience of office hours was found to be the biggest barrier to office hour use. Approachability of the instructor did not predict office hour use, and the only instructor-specific variable that predicted office hour use was the perceived usefulness of the feedback students expected to receive. In another exploratory study, Chung and Hsu (2016) compared the use of office hours with attendance of open course session for students in large physics and symbolic logic courses. Students were welcome to come-and-go and could observe other students asking questions or working with the instructor or teaching assistants. Sixty-seven percent of the students reported preferring the open course center. Students reported that they felt somewhat pressured to have specific questions to ask if they attended office hours but did not feel pressured in the open course session. Accordingly, if students do not know what questions to ask their instructors during office hours, the potential for them to receive help prior to an exam, or receive useful feedback after an examination, is limited.

When considering the impact of office hour attendance on grade outcomes, Guerrero and Rod (2013) found that office hours "have a real, and substantial effect on academic performance" (p. 403) in a political science course at their university. In the Guerrero and Rod (2013) study, the instructors examined 406 undergraduate students over four years of undergraduate study. After controlling for age, gender, college GPA, class standing, family income, and academic major, each office hour visit corresponded to a 0.72% increase in a student's final grade. However, the authors mentioned that these courses have a significant subjective grading component; therefore, greater interaction between the student and the instructor may have influenced grading. Similar to other studies, 54% of the students in these courses never attended office hours and 29% reported attending once or twice. Thirty-six percent of students surveyed claimed that the office hours did not fit into their schedule, which is consistent with the findings of Griffin (2014). Twenty-seven percent claimed they forgot to attend, 24% claimed they did not need help, and 13% claimed they were too hesitant to ask for help (Guerrero and Rod 2013).

In the present study, Health Sciences (HSCI) and Nursing (NURS) students at a large Mid-Atlantic private university were required to take three consecutive anatomy and physiology courses over three academic quarters as part of their undergraduate curriculum. Each of these courses had the same grading format: a midterm examination and a non-cumulative final examination, each worth 30% of the overall grade. Due to the time limitations of a 10-week quarter, and the potential for exams to be copied and shared with future students, students were not "handed back" their exams, and exams were not reviewed in class. Other assessments included five laboratory quizzes (4% of final the grade each), and a weekly quiz (2% of the final grade each). The weekly quizzes were open book and they were due prior to the lecture session on the material.

The Anatomy and Physiology I course covered cell biology, tissues, the muscular and skeletal systems. Anatomy and Physiology II covered the nervous, digestive and endocrine systems. Anatomy and Physiology III covered the immune, cardiovascular, respiratory, urinary and reproductive systems. The HSCI students started the anatomy and physiology series during their sophomore year, while the NURS curriculum scheduled the anatomy and physiology series during the freshman year. There is very high enrollment in these courses. As enrollment in these courses grow, it will be more important than ever to identify the most effective method of exam review that will lead to better performance. Whether attending face-to-face exam reviews with the instructor will have a positive impact on future exam performance is currently unknown. Therefore, the purpose of this investigation was to determine if attending a face-to-face midterm exam review with the instructor predicts final exam performance in an anatomy and physiology I course.

Methods

The Drexel University Institutional Review Board approved this retrospective examination in March 2018, IRB Protocol #: 1801006007. In the Fall of 2017, 292 students were enrolled in Anatomy and Physiology I. The same instructor taught all students. Class year and high school GPA were obtained from the University. The instructor obtained grades on the midterm and final examination from the Blackboard Learn system.

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Exam Review Sessions

All students who were enrolled at the time of the midterm exam were invited to attend office hours to review their midterm exams in small groups. Students were sent a link via a Doodle poll to choose a 30-minute time slot that was convenient for their schedule. The script of the email invitation follows:

> *"Hi everyone! Below is the link for the doodle poll. Carefully follow the instructions. You may only choose one appointment. Please write down the day and time, and location, as you will not be able to log back in to view it again. Whatever you choose is your appointment time.* Please reserve discussion *about your exam until during, or after your appointment. It is helpful to see where you went wrong during the test before discussing better studying strategies!"*

When students followed the link to the poll, they could see that these sessions would be in small groups of three to four students. The rationale for group sessions was to serve as many students as possible, reduce the time burden on the instructor, and to help students feel a sense of community and support in learning (Chung and Hsu 2016, Tinnon 2018). Sessions were scheduled throughout the week to minimize the potential for time conflicts. Students were told to email the instructor if none of these times worked for them.

Exam review sessions were held in either the instructor's office or a reserved conference room. During the exam review sessions, students were required to identify at least two strategies for exam improvement suggested by the instructor. The suggested strategies are outlined in Table 1. Before leaving the exam review session, students were asked to complete an anonymous survey via Survey Monkey about the perceptions and outcomes of the exam review sessions. Forty of the 71 students (56.3%) who attended the exam review appointments responded to the survey. For question 1 of the survey, the instructor asked the following questions:

1. "If the professor had not invited you to view your exam, would you have requested to do so?"
2. "After this appointment, will you change the way you prepare for the final exam?"
3. "After this appointment, what changes will you make to your studying?" Students were allowed to choose all that applied.

Table1. Suggested Strategies During Appointment Meetings to Improve Exam Performance

Before Exam	During Exam
Reading summaries	Process of elimination
Quizzing by a friend or peer	Careful reading of question
Drawing and concept mapping	Recall what knowledge is known to make connections with question content
Minimize distractions	Change answers only when new information is gained
Hand written note taking	

Statistical Analyses

Students were excluded from the analysis if they did not take both exams or were repeating the course, which brought the final sample from 292 to 273 students. A preliminary power analysis was performed with G*Power (Faul *et al.* 2007), version 3.1, to detect a medium effect size of .15 with 80% power. We determined that a sample size of 77 would yield this power threshold given the effect size expected with three predictors. Our sample of 273 students was therefore sufficient and adequately powered to perform the current investigation. The instructor removed all student personal information from the data file prior to statistical analysis. To determine whether midterm exam scores, high school GPA and appointment (dummy coded: 1 = attended; 0 = not attended) significantly predicted final exam scores, we performed a multiple linear stepwise regression procedure. Students were excluded from the statistical analysis if they did not take both exams. Data were screened for normality and homogeneity of variances. All statistical analyses were performed using IBM SPSS software, version 24 with alpha levels set *a priori to* $p<.05$.

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Results

Two hundred and seventy-three students completed Anatomy and Physiology I in the Fall of 2017. The sample included 191 nursing (NURS) and 58 health science (HSCI) students. The majors of the remaining 24 students varied and included nutrition and food sciences, biology, physics, chemistry, behavioral health counseling, public health, dance, provisional studies, electrical engineering, general business, study abroad, and first year exploratory studies. Of the 273 students who completed Anatomy and Physiology I, 71 students responded to the poll and attended the midterm review sessions. Freshman NURS majors made up the majority of the attendees (42 out of 71). The average score on the midterm exam for the entire cohort was 75.7%. There were no significant differences in midterm exam scores among students who attended review appointments (Appt-attend: $M = 76.63$, $SD = 13.19$) and those who did not attend (Appt-not: $M = 74.8$, $SD = 14.03$), $F(1,271) = .944$, $p = .332$. However, there were significant differences in final exam scores between the groups: Appt-attend: $M = 76.86$, $SD = 14.23$ and Appt-not: $M = 72.64$, $SD = 15.12$, $F(1,271) = 4.21$, $p = .04$. The difference in final exam scores between the groups (Table 2) resulted in a small to medium effect size, adjusted for the difference in students between groups ($g = .29$, CI: .02 - .56). Cohen (1988) provided effect size interpretation general guidelines: .20 is considered a small effect, .50 a medium effect, and .80 a large effect.

Table 2. Exam scores (means± standard deviation) by review session attendance

	Attend (n = 71)	Not Attend (n = 202)
Midterm Exam Scores	76.6 ± 13.2	74.8 ± 14.0
Final Exam Scores	76.9 ± 14.3	72.6 ± 15.1

The regression model (Table 4) indicated that 58% of the variance in final exam scores were predicted by midterm exam scores, high school GPA and appointment (adjusted R2=.58, $F(3, 269) = 125.99$, $p <.000$). Adding exam review meeting attendance as a predictor to the model accounted for an additional 0.6% of the variance in final exam scores (Beta = .081, $t(269) = 2.05$, $p =.042$).

Table 3. Regression Model variable correlations

	1	2	3
1. Final Exam			
2. Midterm Exam	.75*		
3. High School GPA	.177*	0.070	
4. =1 if Exam Appt attended	.124*	0.059	-0.002
**Sig. (1-tailed)*			

Table 4. Regression Model for A&P 101 Final Exam Scores

	β	SE	Beta	*t*	*P*
Adjusted R^2 = .58					
Midterm Exam Scores	.799	.04	.736	18.65	.000
High School GPA	1.73	.542	.126	3.19	.002
Exam review appointment attended	2.75	1.34	.081	2.05	.042

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Student Survey Responses

The results of the student survey are presented in Figures 1, 2 and 3. Twenty-nine of the 41 (70.7%) respondents chose responses that indicated that they would not have come for an exam review session without the invitation by the instructor (Figure 1). Thirty-one (75.6%) of the respondents indicated that they would change the way they study for the next exam. Only two students (4.9%) indicated that they would not change anything and were satisfied with their grade. The choices, "test myself more frequently" and "focus more on understanding and applying, rather than memorizing" were most commonly chosen, followed by "studying every week rather than a few days before the exam." The least chosen preparation approach was "post in the discussion board more frequently or meet with professor."

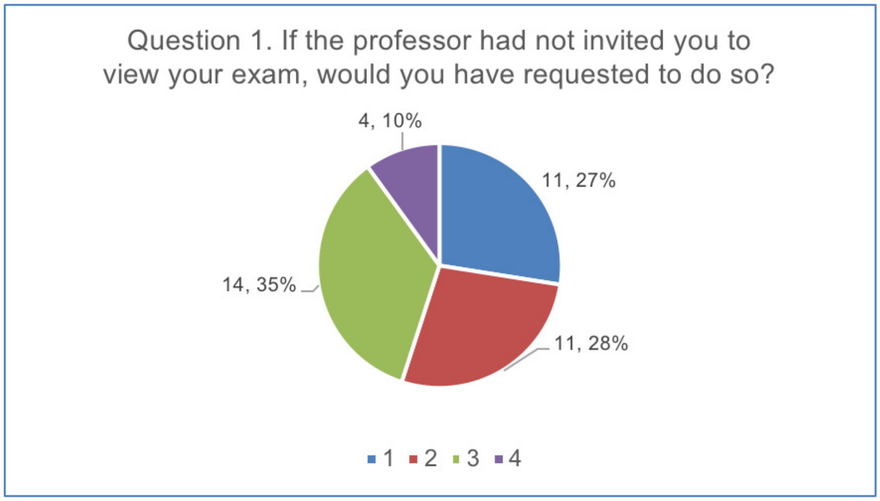

Figure 1. Responses to survey question 1
1 - I would have emailed the professor anyway to set up an appointment.
2 - I would not have emailed the professor to set up an appointment.
3 - I wouldn't have known that I was allowed to come view my exam.
4 - I would have been too embarrassed to reach out to the professor to discuss my exam.

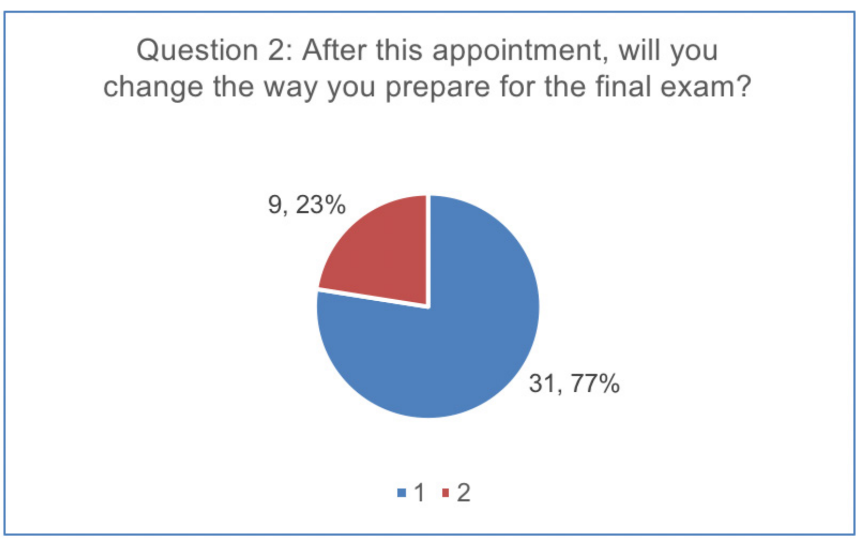

Figure 2. Responses to survey question 2
1 - I will change the way I study for the next exam.
2 - I will continue what I did before, as I am happy with my results.

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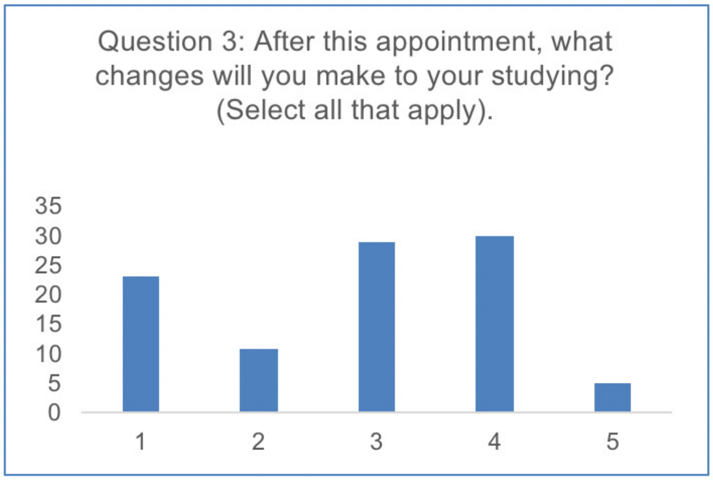

Figure 3. Responses to survey question 3
1 - Study every week, rather than the few days before the exam
2 - Ask for help more often in the discussion board, or meet with professor
3 - Test myself more frequently with the quizzes, a friend or other resources
4 - Focus more on understanding and applying, rather than memorizing
5 - No changes; I am satisfied with my grade

Discussion

Instructors teaching Anatomy and Physiology need to know which strategies are most effective in helping their students learn from their mistakes and improve their grades. Attending an appointment to review the midterm exam in a small group of student peers significantly predicted future exam performance in an Anatomy and Physiology I course in this study. High school GPA also predicted midterm and final exam scores. Finally, midterm exam scores significantly predicted final exam scores. Although the exam review appointment predictor explained a small percentage of the variance in final exam scores, the mean difference on the final exam between attendees and non-attendees was 4.3 points, which has practical significance and may determine whether a student passes or fails the course. This study contributes to previous findings that have found that attending an exam review with the instructor can positively impact future exam performance.

In a recent study of a critical care nursing course, Wiles (2015) examined the impact of exam review appointments with the addition of a developed testing grid. The intent of this grid was to analyze gaps in information or preparation strategies. Students who failed the first exam were strongly encouraged to meet with the instructor to review the exam. Students who met with the instructor to review the exam and complete the test grid analysis improved their score on the second exam by an average of 9.6 points (range -1 to 21), versus students who did not attend these face-to-face meetings (3.1 points, range -5 to 10). Some of the students in this course waited until failing their second or third exam to meet with the instructor, but a number of these students still failed the course despite improvements on the final exam. Fourteen of the students never came to review any exams and eleven of them failed the course (Wiles 2015). The author suggested that the improved scores on the exam were the result of more focused studying on areas identified as "gaps" in the test analysis grid (Wiles 2015). Since the students in the Wiles study were seniors in an advanced critical care nursing course, research is needed to determine if such a structured feedback process will produce similar dramatic improvements for anatomy and physiology students.

The timing of exam review appointments may be particularly important if student expectations of their grades are not aligned with their outcomes. In a study by Eagleton (2015) on learning satisfaction in anatomy and physiology, 56% of students surveyed underestimated the level of preparation that was expected for studying anatomy and physiology and only 57% felt that their grades reflected their effort. Similarly, researchers in a 2016 study examining intrinsic and extrinsic motivation of anatomy and physiology students found that 66% of the students overestimated their final grade (Sturges *et al.* 2016). If students are aware that their expectations for course performance are not realistic before, or at the point of the midterm examination, they may make changes in

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their academic behaviors. These changes may mean that the students can continue on to the next anatomy and physiology course with their cohort and avoid the feelings of failure associated with repeating a course.

Tinnon (2018) reported findings related to the use of a novel test review process utilized in three cohorts of nursing students. In this investigation, students who failed the first exam were required to attend a test review session, which could either be done one-on-one with the instructor, or with another student. The author observed that the students who chose to meet in pairs benefited from hearing the thought processes of fellow students. At these sessions, students were required to reflect on each of their missed exam items and provide a rationale to the instructor for the correct answer. Test-taking strategies, such as process of elimination, reading questions carefully and searching for key words were also discussed. Finally, the instructor also discussed learning styles and study skills with the students.

Students were required to end the test review session by writing down what they learned from the review session and set goals for improvement. While no data on student outcomes was included in this article, the author reported that retention in the course increased significantly in the courses in which the test review was used, and 84% of the students who were failing after the second exam improved their grades and passed the course (Tinnon 2018). The author added that students often returned to tell faculty that the strategies they learned during test reviews were helpful in their subsequent coursework (Tinnon 2018). Although the specific classes and the content of these classes was not provided by the author, the process of test review outlined in this article is similar to our current investigation and provides support to continue the exam review process.

While grades may be positively influenced by faculty interactions and office hours, students may benefit in other ways from interaction with faculty while attending exam review sessions. Academic self-concept, the belief students have in their academic skills and abilities, can be influenced by faculty interactions (Reynolds 1988). Komarraju *et al*. (2010) studied the role of student faculty interactions to increase self-efficacy and engagement. In this study, students who perceived faculty as being less interested in their success reported feelings of discouragement and greater feelings of apathy about course outcomes (Komarraju *et al*. 2010). Conversely, students who perceived faculty as being approachable, respectful, and available for help, reported feeling more confident in their skills and motivated to succeed. Micari and Pazos (2012) set out to examine the impact of the student-faculty relationship in organic chemistry, a course they considered highly challenging. The authors hypothesized that a positive student-faculty relationship would be associated with better student performance, greater confidence, and a sense of identity in the sciences.

A 12-item Likert scale was developed to assess the quality of the student faculty relationship and student confidence in the course. A stepwise linear regression model was created that included college GPA, gender, and minority status as covariates along with the studentfaculty relationship score. Student-faculty relationship was a significant predictor of grade (R2 = .512), with the items "looking up to the professor," "feeling comfortable approaching the professor", and "feeling the professor respects the students" as the strongest predictors. While this is meaningful, a stronger relationship existed between student-faculty relationship and student confidence in their ability to succeed than between student-faculty relationship and grades. For every unit increase in student-faculty relationship, the authors reported an expected .171 increase in the final grade in the course, but a .448 unit increase in student confidence (Micari and Pazos 2012). Since the anatomy and physiology course series is required for students in our undergraduate nursing and health sciences curriculum, more research on the impact of the faculty-student interaction on both grades and student confidence in anatomyh and physiology courses is warranted.

Of the three predictors included in the regression model in the current investigation, midterm exam performance was the strongest predictor of final exam performance. Anecdotally, students often feel that their midterm exam performance is not indicative of their future exam performance and that their grade was not truly reflective of their understanding or ability. Sharing the message with students at the beginning of the course that grades on the midterm exam strongly predict grades on the final exam may be enlightening and motivate them to change their behaviors earlier in the course. However, this information should only be shared if effective strategies and support are available to the student following the midterm grade.

There are limitations to address in this study. First and foremost, while meeting with the faculty member to review the midterm exam significantly predicted performance on the final examination, we cannot know whether it was the influence of the instructor, or the actual exam review exercise, that predicted the final exam grade. Simply meeting with the instructor and feeling "seen" may have increased student confidence in their ability to succeed (Micari and Pazos 2012). Future research on exam review appointments could include a group that reviews exams with another faculty member or proctor not involved in the course or compare methods of exam review between review sessions. Students who are struggling in a course may still want to meet with the instructor and this additional meeting may serve as another variable to examine in regard to student performance.

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During the exam review sessions, students were required to identify two strategies for improvement. This provided structure to the exam review appointment and a goal for the session. However, these strategies were not monitored for the remainder of the course, so it is unknown whether the students followed the suggested strategies or if the strategies led to improvement on the final exam. Alternatively, students who were already motivated to improve their grades may have been the students who came to view their exams. It is possible that these students would have improved their grades by seeking out tutoring, studying more regularly, or testing themselves more frequently after seeing their midterm exam results. Without formal tracking of student behaviors and behavior change following the instructor meeting, the question of exactly *why* students who viewed their exams improved remains an area for future research. The results of the anonymous survey indicated that most students planned to change their studying approaches. Therefore, future research should include a method to track students after exam review sessions. Finally, information on high school anatomy and physiology courses, or other relevant coursework in high school that may have prepared students for anatomy and physiology, was not available.

Conclusions

Face-to face exam review significantly predicted final exam grades in our large sample of HSCI and NURS students, but midterm exam scores explained most of the variance in final exam scores. Exam review appointments should be continued and enhanced to include a more structured analysis of the midterm exam. Follow up with students should include implementation of new studying strategies before the final exam. Anatomy and physiology instructors who are currently not reviewing examinations individually, or in small groups, may consider implementing an exam review plan that suits the course schedule.

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Literature cited

Anderton R, Evans T, Chivers P (2016) Predicting Academic Success of Health Science Students for First Year Anatomy and Physiology. *International Journal of Higher Education*. 5(1).

Chung C, Hsu L (2016) Encouraging Students to Seek Help: Supplementing Office Hours with a Course Center. *College Teaching*. 54(3):253-258.

Cohen, J (1988) Statistical power analysis for the behavioral sciences (2nd ed.) Hillsdale, NJ: Erlbaum.

Eagleton S (2015) An Exploration of the Factors That Contribute to Learning Satisfaction of First-Year Anatomy and Physiology Students. *Advanced in Physiology Education*. 39:158-166.

Faul F, Erdfelder E, Lang A, Buchner A (2007) G* Power 3: A Flexible Statistical Power Analysis Program for the Social, Behavioral, and Biomedical Sciences. *Behavioral Research Method*s. 39(2):175-191.

Griffin W, Cohen SD, Berndtson R, Burson KM, Camper KM, Chen Y, Smith, MA (2014) Starting the Conversation: An Exploratory Study of Factors That Influence Student Office Hour Use. *College Teaching*. 62.

Guerrero M and Rod A (2013) Engaging in Office Hours: A Study of Student-Faculty Interaction and Academic Performance. *Journal of Political Science Education*. 9(4):403-416.

Gultice A, Witham A, Kallmeyer R (2015) Are Your Students Ready for Anatomy and Physiology? Developing Tools to Identify Students at Risk for Failure. *Advances in Physiology Education*. 39.

Komarraju M, Musulkin S, Bhattacharya G (2010) Role of Student-Faculty Interactions in Developing College Students' Academic Self-Concept, Motivation, and Achievement. *Journal of College Student Development*. 51(3):332-342.

Micari M, and Pazos P (2012) Connecting to the Professor: Impact of the Student-Faculty Relationship in a Highly Challenging Course. *College Teaching*. 60:41-47.

Reynolds WM (1988) Measurement of Academic Self-Concept in College Students. *Journal of Personality Assessment*. 52(2):223-240.

Rompolski K, Smith S, Flynn M, Kirifides M, Samendinger S (2016) Predictors of Success of Nursing and Health Science Students in Anatomy and Physiology. *HAPS Educator*. 20(4).

Russell B, Young K, Lehning E (2016) Distribution of and Factors Associated with Anatomy and Physiology I Grades at a Community College. *HAPS Educator*. 20(4):7-21.

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Schutte A (2015) Who is Repeating Anatomy? Trends in an Undergraduate Anatomy Course. *Anatomical Sciences Education. 9*(2).

Sturges D, Maurer T, Allen D, Gatch D, Shankar P (2016) Academic Performance in Human Anatomy and Physiology Classes: a 2-year study of academic motivation and grade expectation. *Advances in Physiology Education*. 40:26-31.

Tinnon E (2018) Reflective Test Review: The First Step in Student Retention. *Teaching and Learning in Nursing.* 13(1):31-34.

Wiles L (2015) "Why Can't I Pass These Exams?" Providing Individualized Feedback for Nursing Students. *Journal of Nursing Education.* 54(3):555-558.

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Voluntary Web-Based Self-Assessment Quiz Use is Associated With Improved Exam Performance, Especially for Learners with Low Prior Knowledge

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Abstract
This study examined students' voluntary use of digital self-assessment quizzes as a resource for learning in a large anatomy and physiology lecture course. Students (n = 238) could use 16 chapter quizzes and four analogous unit quizzes to rehearse and self-assess knowledge. Most students (75%) engaged in occasional use of self-assessment quiz items; repeated use was uncommon (12%), as was lack of use (13%). Exam performance differed between quiz use groups. Quiz use improved exam performance more among students who entered the course with low prior knowledge of concepts from the prerequisite course. Cumulatively for all students and all exams, repeated self-assessment quiz users significantly outperformed occasional users (+7.5%) and non-users (+11.9%) on course exams. Incorporation of optional learning resources can enhance the learning success of students.
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Key words: retrieval practice, digital resources, large enrollment, at-risk students, anatomy and physiology

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Introduction
Studies in the United States and abroad indicate that preparatory courses (e.g. Human Physiology, Human Anatomy and Physiology) for students pursuing healthcare professions can be challenging (Higgins-Opitz and Tufts 2013, Hopp 2009, Sturges *et al.* 2016). For example, one study of Human Anatomy and Physiology I students from a small liberal arts college in the southwestern US reported that 43.6% of students (n = 546) earned a W, D, or F at the end of the term (Hopp 2009). An investigation at a southeastern US university documented the grade expectations for over 1200 students enrolled in Human Anatomy and Physiology classes; 65.5% of students overestimated their final course grade (Sturges *et al.* 2016). A study of a first-semester Human Physiology course at an ethnically diverse South African university documented a 54% pass rate for students in a large enrollment (n = 214) course (Higgins-Opitz and Tufts 2013). Improving student learning success in early science courses is a priority for both educators and institutions (Holdren and Lander 2012). Among other major recommendations to the STEM education community, advisory councils recommend that achievement can be increased if educators build useful resources for students and incorporate "active learning" that aligns to learning processes known to improve performance (Holdren and Lander 2012).

Quizzes that can be completed without impact on a course grade are a common learning resource that provides an opportunity for students to engage in "active learning." Active learning is a large category of learning activities that subsume many different processes, including some processes known to promote learning and positively affect performance (Freeman *et al.* 2014, Michael 2006, Prince 2004). One example is students' use of diagrams and figure captions or associated text as a resource to engage in *self-explanation*, wherein the practice of rehearsing one's knowledge orally or in writing improves retention of the knowledge. For example, students tend to perform better on later assessments when they are prompted to self-explain how a biological system works (e.g. the circulatory system, Chi *et al.* 1994). A similar principle can be observed when students engage in *retrieval practice*, a method commonly used to learn factual or declarative knowledge (Karpicke and Blunt 2011). Like self-explanation, students actively engage with targeted content by repeatedly attempting to retrieve answers in response to stimuli.

Students who use retrieval practice or self-explanation methods tend to perform better than those who take more passive approaches like re-reading biology texts (Dunlosky *et al.* 2013). Students who use retrieval practice also tend to

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perform better than those who utilize more engaging learning strategies like elaborative concept mapping (Karpicke and Blunt 2011). Both self-explanation and retrieval practice have the added benefit of generating correctness feedback and opportunities to compare students' answers to models. These opportunities enable students to engage in *metacognitive monitoring* (Winne and Hadwin 1998). When students attempt quiz questions on a digital platform, the software can judge their correctness, and thus the quality of their knowledge on topics. Students can monitor this feedback, make judgments about their level of knowledge compared to standards set by course objective, and they can plan their future study accordingly. Active learning strategies, like retrieval practice, are potent and can improve performance, but students tend not to use them in authentic learning environments like their large lecture courses. Research on student learning shows that students tend to opt for minimally effective strategies like re-reading over more effective strategies like retrieval practice and self-explanation (McCabe 2011). This study examined the effect of providing a bank of ungraded digital self-assessment quizzes on student achievement in a large Anatomy and Physiology I lecture course.

The research questions that were investigated include:

1. What percentage of students will make use of the digital quizzes provided to them? How many will use the digital quizzes in a repeated fashion, which might provide benefits associated with retrieval practice and metacognitive monitoring processes?
2. Do students who use digital self-assessment quizzes to differing extents perform differently on course exams?
3. How do the benefits of self-assessment quizzing differ for students with differing levels of prior knowledge?

Methods

Data were collected from students (n = 238) enrolled in a Human Anatomy and Physiology I course at the University of Nevada Las Vegas (UNLV). Two 75-minute lectures were scheduled each week for 15 weeks. Final exams were conducted during the 16th week of the semester. Students attended one 165-minute laboratory session each week. Lecture sections for this course typically contain 180 to 220 students; laboratory sections contain a maximum of 24 students and are typically taught by graduate students. The lecture course has an associated learning management system (LMS; Blackboard Learn) where the instructor provided a variety of resources for students (e.g., chapter learning objectives, lecture presentations, and self-assessment quizzes). Students were introduced to these resources during the first lecture of the semester and utilized them on a voluntary basis thereafter. Course exam structure and content are indicated in Table 1.

All self-assessment quizzes were available to students throughout the entire semester; the Blackboard Learn site opened 1 week prior to the start of instruction and closed 2 weeks after the end of instruction. Quizzes had no time limit and unlimited attempts were allowed. The description stated, "You can use this quiz as often as you wish to test your mastery of the terms and concepts covered in this chapter of the course." Students could use (or not use) the quizzes however they wished. All self-assessment quizzes were composed of a mixture of multiple choice and fill-in-the-blank style questions. The course instructor selected relevant questions from question banks provided by the textbook publisher to build the self-assessment quiz pools. A pool of approximately 35 questions was created for each chapter. Chapter quizzes contained 15 items randomly selected from the pool. Unit quizzes containing 40 items and a 100-item comprehensive quiz covering all chapters were also available. The unit quizzes and the comprehensive quiz pulled questions from the corresponding chapter quiz pools. After submitting a quiz, students received feedback on the correct response as well as the corresponding section of the text. None of the questions utilized for self-assessment quizzes were included on course exams. Course exams were comprised of a mixture of multiple choice questions written by the instructor, test bank questions modified by the instructor, and short answer questions written by the instructor.

After the semester ended, we investigated the effects of self-assessment quiz use and prior knowledge on exam performance. In the context of this study, the phrase prior knowledge is used to describe the knowledge retained from the prerequisite course. Students were grouped by prior knowledge levels into low (n = 84), mid (n = 76), and high (n = 78) terciles based on a 30-item pre-test given at the start of the semester. The pre-test covered general biology content discussed in the prerequisite course. Students in the low prior knowledge group earned pre-test scores in the failing range (< 59%); the mid prior knowledge group earned scores in the C to D range (60 to 79%); the high prior knowledge group earned scores in the A to B range (> 80%). Students were also categorized into groups based on the number of self-assessment quiz items attempted. Students in the "no use" group attempted 0 quiz items over the full semester; students in the "occasional use" group registered between 1 and 400 quiz events; students in the "repeated use" group spanned from 401 through 1478 quiz events. Four hundred events would be observed if a student completed every available self-assessment quiz and registered an answer to each item once.

Before conducting inferential analyses examining differences in exam performance across repeated, occasional, and non-users of self-assessment quizzes, a series of preliminary analyses were conducted to investigate whether the students in these groups differed in their demographics, prior

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achievement, or initial motivation in the course. Chi-squared (χ^2) tests and a one-way multivariate analysis of variance (MANOVA) were utilized for the preliminary analyses. After preliminary analyses were completed, student exam scores were submitted to a 3 (Group) x 4 (Time; exams) mixed analysis of variance (ANOVA). The main effect of time is not pertinent here, thus only the main effect of Group is reported to summarily describe the differences in achievement between user groups. Where pertinent, we supplement by reporting contrasts between groups at specific exam time points, and report interactions where groups demonstrate increasing differences in achievement over time. For each comparison, the magnitude of the effect is included. Data were analyzed using statistical software (SPSS); test statistics producing $p < .05$ were considered statistically significant. The institutional review board for social sciences research at the University of Nevada Las Vegas (UNLV) approved this project, IRB #850677, and informed consent was obtained from all participants.

Table 1. Course Exam Structure and Content

	Type of Exam	Exam Structure	Topics Covered
Exam 1	Unit Exam	50 multiple-choice items and 2 short answer items	homeostasis, chemistry, cells, tissues, and integumentary system
Exam 2	Unit Exam	50 multiple-choice items and 2 short answer items	osseous tissue, axial skeleton, appendicular skeleton, and articulations
Exam 3	Unit Exam	50 multiple-choice items and 2 short answer items	muscle tissue, muscular system, and neural tissue
Exam 4	Comprehensive Final Exam	100 multiple-choice items: 60 items on units 1 through 3 and 40 items on unit 4	topics for units 1-3 listed above spinal cord, brain, autonomic nervous system, and special senses

Results

Student Profile

The undergraduate population at UNLV is diverse, and students enrolled in science courses generally reflect the demographics of the larger population (Figure 1). Students in the Anatomy and Physiology course were categorized into groups based on the number of self-assessment quiz events completed (Figure 2).

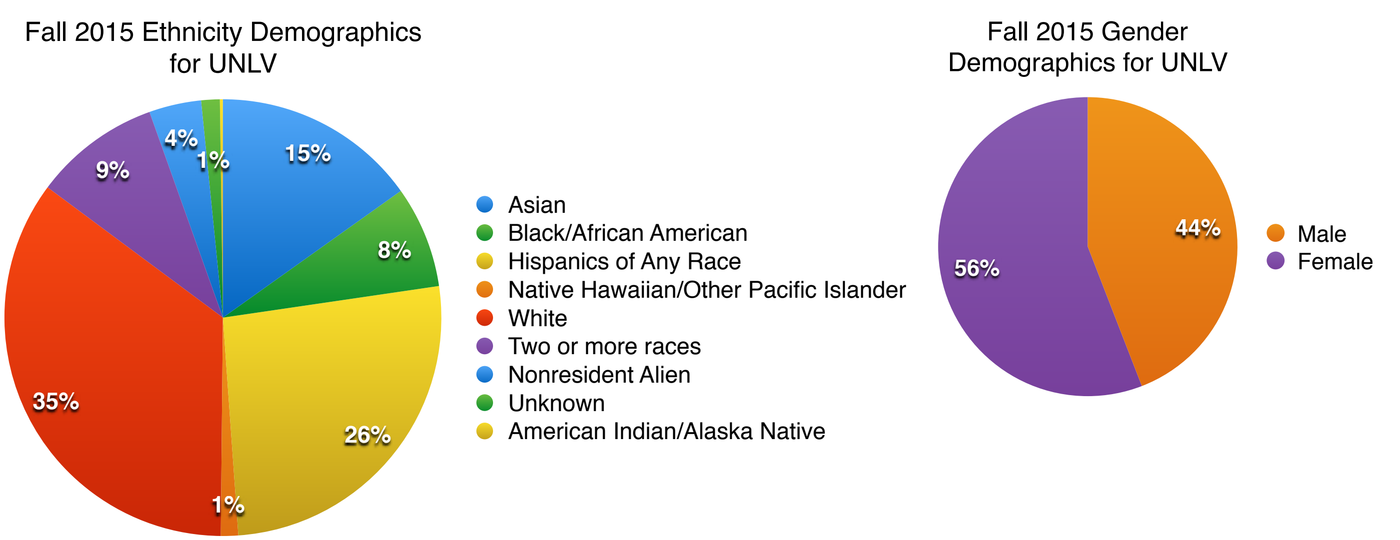

Figure 1. Student Demographics - University of Nevada Las Vegas (UNLV)

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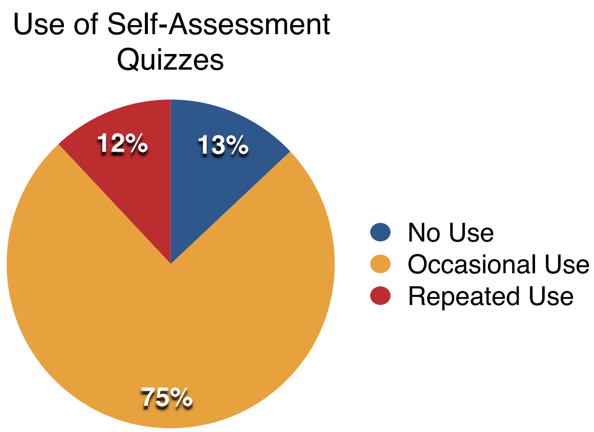

Figure 2. Levels of Voluntary Use of Self-Assessment Quiz Items

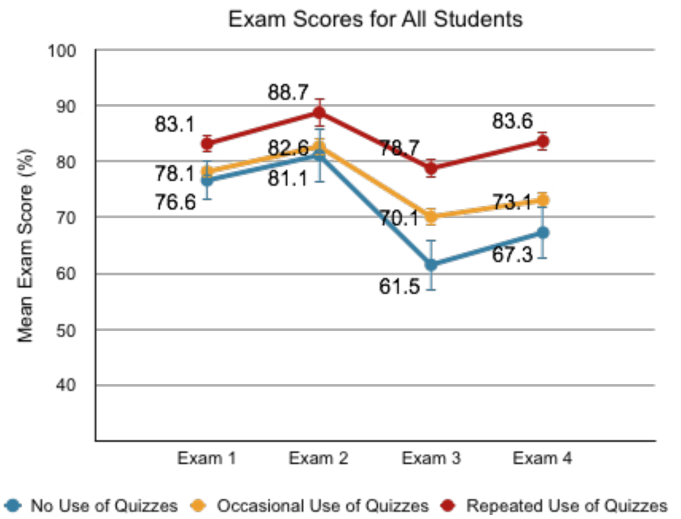

Figure 3. Effect of Self-Assessment Quiz Use on Exam Performance Symbols represent means ± standard error of the mean.

Preliminary Analyses

Preliminary analyses investigated the characteristics of students in the three quiz use groups (none, occasional, repeated). A series of chi-squared (χ^2) tests were conducted to determine whether the three user groups were proportionate in their inclusion of men vs. women, first generation vs. continuing generation college students, or individuals from historically well-represented groups (i.e., Caucasian and Asian-American) vs. underrepresented groups (i.e., Latino/a and African-American). For the whole sample, 12% of students used quizzes repeatedly, 75% percent used them occasionally, and 13% did not use them at all. The χ^2 tests revealed no differences in membership by gender, χ^2 [2, 239] = 0.025, p = 0.998, or generational status, χ^2 [2, 239] = 0.167, p = 0.446. A significant difference in membership by ethnicity indicated that fewer Latino/a and African-American students were repeated quiz users (6%) and more of them were non-users (19%) than would be expected, χ^2 [2, 239] = 6.294, p = 0.043.

A one-way multivariate analysis of variance (MANOVA) was conducted to examine whether self-assessment quiz user groups differed by their prior achievement or achievement motivation for their STEM coursework. At the beginning of the semester, students completed a pretest assessing their retention of knowledge from the prerequisite biology course and completed a battery of motivational scales representing students' self-reported efficacy (Bandura 1977), expectancies and values (Wigfield and Eccles 2000), achievement goals (Elliot and Murayama 2008) for STEM coursework, their perceptions of the values and costs of such coursework, and their general level of academic anxiety and growth mindset orientation. All scales were adopted based on guidelines for their design with specific populations (Bandura 2001) or from prior research with a parallel population (Perez *et al.* 2014) to ensure validity of use. No significant differences were observed across the quiz use groups on this set of measures related to their baseline academic achievement goals and motivation, Wilks' Λ (11, 223) = 1.014, p = 0.445.

Effects of Self-Assessment Quiz Use and Prior Knowledge on Exam Performance

Results of the mixed ANOVA indicated that student use of self-assessment quizzes had a significant effect on course exam performance, F (2, 229) = 5.89, p = 0.003. Post hoc analyses indicated that students who repeatedly used self-assessment quizzes cumulatively scored 7.55% higher on course exams than students who occasionally used quizzes (LSD; p = 0.006) and scored 11.92% higher than students who did not use quizzes (LSD; p = 0.001). Overall, repeated self-assessment quiz users significantly outperformed occasional users and non-users on course exams (Figure 3).

Results of the mixed ANOVA indicated that student prior knowledge level had a significant main effect on course exam performance, F (2, 229) = 18.18, p < 0.001. Overall, students who entered the course with higher levels of prior knowledge outperformed those with lower levels of prior knowledge (Figure 4). Results of the mixed ANOVA indicated an interaction between self-assessment quiz use and prior knowledge level F (4, 229) = 3.51, p = 0.008. Repeated quiz use was associated with greater changes in exam performance for students who entered the course with low levels of prior knowledge (Figure 4A). Students in the low prior knowledge group who repeatedly used quizzes outperformed non-users by nearly 40% on exams 3 and 4, and occasional users outperformed non-users by more than 20% on these exams. Stronger performance on exams 3 and 4 is noteworthy since these exams assess some of the more difficult course concepts (i.e. muscle and neural physiology; Table 1).

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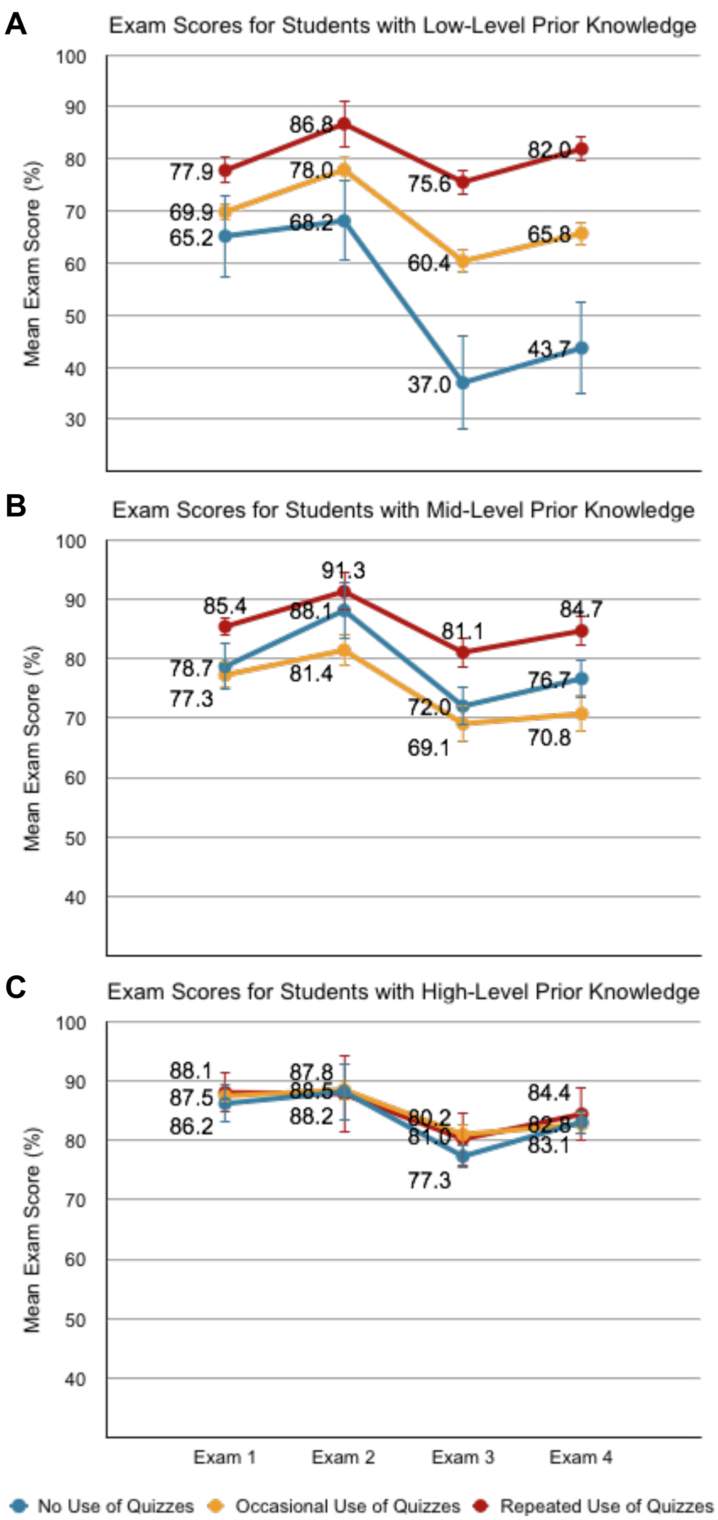

Figure 4. Effects of Prior Knowledge and Self-Assessment Quiz Use on Exam Performance
Symbols represent means ± standard error of the mean.

Discussion

Human Anatomy and Physiology courses are notoriously difficult, and students often enter these courses underprepared. This study investigated the effect of voluntary use of self-assessment quizzes on exam performance. It was documented that digital quiz use substantially improved exam performance, particularly for students with low levels of prior knowledge. This type of course enrichment could benefit students at many diverse institutions across various course sizes and delivery formats (i.e. face to face, hybrid, online). Implementation of this type of self-assessment quiz is aligned with recommendations to improve STEM education through incorporation of evidence-based learning practices (Holdren and Lander 2012). The incorporation of optional quizzes as a learning resource is a reasonable expectation of instructors who can make use of existing resources provided by textbook publishers. Digital quizzes are easily incorporated into LMS course sites; a process that requires limited time investment.

The first research question centered on how students would use *optional* self-assessment quizzes. The effectiveness of retrieval practice via quizzing has been well documented, however many investigations rely on student completion of required quizzes. For example, Norton and Clancy previously documented the effectiveness of digital quizzes in an anatomy and physiology course (2005). In their study, when all students were required to complete two practice quizzes prior to each lab exam, the overall pass rate for the course increased by 8.5% (Norton and Clancy 2005). The Norton and Clancy investigation differs from the current study in a few meaningful ways; all students were required to take multiple practice quizzes, some of the practice quiz questions were included on the subsequent exams, and student subpopulations were not investigated. The present study investigated voluntary use, items on the self-assessment quizzes were not utilized in course exams, and subpopulations of students (i.e. prior knowledge groups) were evaluated. Regarding the level of use, we document that most students (87%) engaged in voluntary use of quizzes that were explicitly intended for self-assessment, with 12% of students repeatedly using the quizzes (Figure 2).

The second research question targeted the relationship between the extent of quiz use and exam performance. The preliminary analyses indicated that students in different quiz use groups did not differ in prior achievement goals or motivation, thus we conclude subsequent differences in exam performance by quiz use groups are likely to have been induced by student learning behaviors (e.g. pattern of quiz use). As might be expected given the opportunities for retrieval practice and metacognitive monitoring, students who repeatedly used self-assessment quizzes earned higher exam scores than other students (Figure 3). However occasional use of quiz items was also beneficial, particularly

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on later exams that covered more conceptually challenging material (Figure 3, Table 1). Cumulatively, for all course exams, repeated quiz users averaged 84%, occasional users averaged 76%, and non-users averaged 72%. The preliminary analyses indicated that fewer Latino/a and African-American students were repeated quiz users (6%) and more were non-users (19%) than would be expected. Given these findings, instructors should consider strategies to ensure all students engage with effective learning resources and are aware of the associated educational benefits that correlate with investing time into effective learning practices.

The third research question examined the relationship between prior knowledge level and various levels of quiz utilization. Even with a prerequisite course in place, students begin a new course with vastly divergent levels of knowledge and skill proficiency. Students in the low prior knowledge group earned a pre-test score that would typically be associated with a failing grade (< 59%). Students in this group who did not use self-assessment quizzes averaged 43.7% on the comprehensive final exam whereas their counterparts who repeatedly used the quizzes averaged 82.0% on the final exam (Figure 4A). These gains in exam performance "closed the gap" between these students and their peers who entered the course with high levels of prior knowledge. Students in the high prior knowledge group who repeatedly used the quizzes averaged 84.4% on the final exam (Figure 4C).

Students in the low prior knowledge group who repeatedly utilized self-assessment quizzes experienced the greatest gains in exam performance. In contrast, there was little difference in exam performance for students in the high prior knowledge group. The nature of the quiz items may have contributed to this lack of effect. The quizzes contained questions targeting lower levels (i.e. recall and comprehension) of knowledge whereas the exams contained a mixture of comprehension and application level questions. Levels of knowledge can be described by common schema such as the original and revisions to Bloom's Cognitive Taxonomy (Anderson *et al.* 2001, Bloom *et al.* 1956) or Webb's (1997) Depth of Knowledge, which underlie standards for science learning. A modification that might better support all students would be development of two (or more) levels of self-assessment quizzes. The first level quiz could contain items targeting foundational, declarative knowledge to be recalled (like the quizzes utilized in the present study), and the second level quiz could contain items targeting more advanced levels like applying and analyzing concepts. Such an approach could provide scaffolding for students with low prior knowledge as well as useful learning resources for students with higher levels of prior knowledge.

Increasing the success of vulnerable student populations is a priority for educational and community stakeholders. Incorporation of evidence-based practices, such as low-stakes quizzing to facilitate retrieval practice and metacognitive monitoring, is one path towards improving educational outcomes in STEM disciplines. This investigation documented that most students used optional self-assessment quizzes, repeat users earned higher exam scores, and gains in exam performance were greatest for students who entered the course with a low level of prior knowledge. Students with low prior knowledge may be considered at-risk for failure. Grade point average (GPA) was found to be the strongest predictor of course grades in a study that examined more than a decade of data from 12 life science courses (Creech and Sweeder 2012). Incorporation of optional quizzes is reasonable for instructors and can dramatically benefit students. Students who began with low prior knowledge and repeatedly used self-assessment quizzes ended the semester with a final exam average within 2% of peers who began with high prior knowledge. In sum, instructors are encouraged to consider incorporating optional learning resources that promote retrieval practice and metacognitive monitoring into their courses.

About the Authors

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Jenifer and Matt have collaborated on a variety of STEM education research projects centered on utilization of digital resources and learning management system data to improve students' cognitive and metacognitive skills, their achievement, and their persistence in the STEM majors.

Literature Cited

Anderson LW, Krathwohl DR, Airasian PW, Cruikshank KA, Mayer RE, Pintrich PR, Wittrock MC *et al.* (2001) A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives, abridged edition. White Plains, NY: Longman.

Bandura A (1977) Self-efficacy: toward a unifying theory of behavioral change. *Psychol. Rev.* 84(2): 191-215.

Bandura A (2001) Guide for constructing self-efficacy scales (Monograph). Stanford, CA: Stanford University.

Bloom BS, Engelhart MD, Furst EJ, Hill WH, Krathwohl DR (1956) Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain. New York: David McKay Company.

Chi MT, De Leeuw N, Chiu MH, LaVancher C (1994) Eliciting self-explanations improves understanding. *Cogn. Sci*. 18(3): 439-477.

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Creech LR, Sweeder RD (2012) Analysis of student performance in large-enrollment life science courses. *CBE – Life Sci. Educ*. 11(4): 386-391.

Dunlosky J, Rawson KA, Marsh EJ, Nathan MJ, Willingham DT (2013) Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychol. Sci. Public Interest* 14(1): 4-58. doi:10.1177/1529100612453266

Elliot AJ, Murayama K (2008) On the measurement of achievement goals: Critique, illustration, and application. *J. of Educ. Psychol.* 100(3): 613-628.

Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, Wenderoth MP (2014) Active learning increases student performance in science, engineering, and mathematics. *PNAS* 111(23): 8410-8415.

Higgins-Opitz SB, Tufts M (2013) Performance of first-year health science students in a large, diverse, multidisciplinary, first-semester, physiology service module. *Adv. Physiol. Educ*. 38: 161-169. doi:10.1152/advan.00067.2013.

Holdren JP, Lander ES (2012) Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics (Executive Report). Washington, D.C.: President's Council of Advisors on Science and Technology.

Hopp RMP (2009) A success story: chemistry before Anatomy and Physiology I. *HAPS Educator* 14(1): 56-59.

Karpicke JD, Blunt JR (2011) Retrieval practice produces more learning than elaborative studying with concept mapping. *Science*. *331*(6018): 772-775.

McCabe J (2011) Metacognitive awareness of learning strategies in undergraduates. *Mem. Cognition*. 39(3): 462-476.

Michael J (2006) Where's the evidence that active learning works? *Adv. Physiol. Educ*. 30: 159-167. doi:10.1152/advan.00053.2006.

Norton JD, Clancy AN (2005) Use of on-line practice quizzes enhances student performance in anatomy and physiology. *HAPS Educator* 9(2): 10-11.

Perez T, Cromley JG, Kaplan A (2014) The role of identity development, values, and costs in college STEM retention. *J of Educ. Psychol*. 106(1): 315-329.

Prince M (2004) Does active learning work? A review of the research. *J. of Engineering Educ*. 93: 223-231. doi: 10.1002/j.2168-9830.2004.tb00809.x

Sturges D, Maurer TW, Allen D, Gatch DB, Shankar P (2016) Academic performance in human anatomy and physiology classes: a 2-yr study of academic motivation and grade expectation. *Adv. Physiol. Educ*. 40: 26-31. doi:10.1152/advan.00091.2015.

Webb NL (1997) Criteria for alignment of expectations and assessments in mathematics and science education (Research Monograph No. 6). Madison, WI: University of Wisconsin-Madison, National Institute for Science Education.

Wigfield A, Eccles JS (2000) Expectancy-value theory of achievement motivation. *Contemp. Educ. Psychol.* 25(1): 68-81.

Winne P, Hadwin A (1998) Studying as self-regulated learning. In Hacker D, Dunlosky J, and Graesser A (eds.). (pp. 279–306). *Metacognition in Educational Theory and Practice*, Erlbaum: Hillsdale, NJ.

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Ankylosing Spondylitis: Anatomical Associations and Novel Therapeutic Research

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Abstract
Ankylosing spondylitis (AS) is a progressive, inflammatory, autoimmune disease that primarily affects the sacroiliac joints and the axial skeleton of young Caucasian males. The disease can also affect extra-articular regions of the body such as the cardiovascular system, the eyes, and the skin. The pathogenesis of the disease is not well understood but research is centered on immune mediation, genetic factors, environmental factors, and bacterial agents. This article examines the anatomical regions that are most affected by AS and novel therapeutic research findings.
https://doi.org/10.21692/haps.2018.018

Key words: ankylosing spondylitis, HLA-B27, Wnt/β-Catenin signaling pathway, tumor necrosis factor (TNF), enthesis, aortitis, uveitis

The information contained in this article will enhance student comprehension of the skeletal, cardiovascular, visual, and digestive systems and their appreciation for the current research associated with Ankylosing Spondylitis and related skeletal, cardiovascular, eye, and gastrointestinal pathologies. This material can be used to enhance the pedagogy of courses in Human Anatomy and Human Anatomy and Physiology.

Introduction
Ankylosing spondylitis (AS) is the prototypical disease in a group of inflammatory, autoimmune conditions known collectively as spondyloarthritides or spondyloarthropathies (SpA). In addition to AS, the group includes psoriatic arthritis, reactive arthritis, inflammatory bowel-disease-associated arthritis, and undifferentiated spondyloarthritis (Benjamin and McGonagle 2001, Gouveia *et al.* 2012, Haynes *et al*. 2012). All of these conditions are characterized by inflammatory arthritis, systemic inflammation, bacterial infection of the bowel, seronegativity for the presence of rheumatoid factor in the blood, and a strong association with human leukocyte antigen, HLA-B27 (Benjamin and McGonagle 2001).

AS is a chronic, progressive disease characterized by inflammation of the sacroiliac joints and the axial skeleton. The disease may also affect peripheral joints and extra-articular regions of the body such as the cardiovascular system (aortitis), the eyes (uveitis), and the skin (psoriasis) (Gouveia *et al. 2012,* Palazzi *et al.* 2010, Smith 2014). Inflammation is often most pronounced in the entheses, areas where tendons, ligaments, and joint capsules attach to bones. Inflammation of the enthesis is known as enthesitis (Benjamin and McGonagle 2001). As the disease progresses, enthesitis is associated with diffuse osteitis in the adjacent bone. Skeletal complications of AS may include inflammatory erosive osteopenia (weakened bone) and the overgrowth of new bone. Linkages of areas of syndesmophyte (bone spur) formation between the vertebrae of the spine and calcification of intervertebral discs can produce a characteristic fusion of the vertebrae known as "bamboo spine", which can result in a rigid, stooped posture and significant disability (Gouveia *et al.* 2012, Sieper *et al.* 2002, Smith 2014). The progressive nature of the disease means that diagnosis is often delayed eight to ten years after the first onset of symptoms; time during which treatment has not been made available to the patient. This is unfortunate because the most effective treatments seem to work best when given early in the progression of the disease (Smith 2014).

AS primarily affects young Caucasian men who are HLA-B27 positive. The average age of onset is before age forty, typically between twenty and thirty. The mean age of onset is twenty-six years (Braun *et al.* 2004). Most of the functional losses associated with the progression of AS occur during the first ten years of the disease (Gouveia *et al.* 2012). The association between AS and HLA-B27 is strong in Caucasian patients, with approximately 92% testing positive for HLA-B27. The association with HLA-B27 is not as strong in other ethnic groups (Gouvenia *et al.* 2012, Bluestein 1988).

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AS is considered to be a common disease with prevalence from 0.1% to 1.4% of the world population (Gouveia *et al. 2012,* Smith 2014*)*. It varies according to sex, ethnicity, and geography with the highest number of cases diagnosed in Caucasian males. AS is extremely rare in African black populations, where the presence of the HLA-B27 gene is also rare (Gouveia *et al. 2012*). Men are affected in a three-to-one ratio over women and the disease is often more severe in men. Most female patients are diagnosed later in life and they tend to have a wider range of AS symptoms that extend throughout the body, with less specific involvement of the spine (Palazzi *et al.* 2010).

Extra-articular complications include aortic valve disease, aortic insufficiency, conduction abnormalities of the heart, periaortitis, superior-lobe pulmonary fibrosis, gastroenteritis, anterior uveitis, urinary tract inflammation, and *cauda equina* syndrome (Mitchell *et al.* 1990, Palazzi *et al.* 2010, Sant and O'Connel 1995).

X-ray shows Ankylosing spondylitis and Scoliosis

The treatment for AS is focused on pain relief and the reduction of inflammation. It typically consists of a combination of non-steroidal anti-inflammatory drugs (NSAIDs) and physical therapy. Both are palliative care options that do not change the course of the disease or prevent tissue damage. When NSAIDs are not effective, corticosteroids are sometimes used. A new generation of anti-tumor-necrosis-factor drugs seems to be able to more effectively relieve symptoms but may not be able to change the course of the disease for the majority of patients (Gouveia *et al.* 2012).

This article examines the anatomy and novel therapeutic research findings associated with AS.

Vertebral Disease in AS

Clinical symptoms of vertebral involvement in AS can range from mild stiffness to spinal fusion. These symptoms may occur with any combination of hip involvement, arthritis, or extra-articular involvement (Sieper *et al.* 2002).

The first symptoms noticed by patients with AS are typically pain that is felt deep in the buttock and/or in the lower lumbar region, accompanied by morning stiffness in the same areas (Sieper *et al.* 2002). Both are relieved with exercise and become more noticeable with rest or lack of activity. These symptoms are often associated with asthenia (physical weakness), fatigue, elevated body temperature, and weight loss (Gouveia *et al.* 2012, Sieper *et al.* 2002).

Vertebral involvement associated with AS starts in the sacroiliac joints and is usually bilateral. Over time the disease progresses superiorly into other regions of the spine. Thirty-three percent of patients experience enthesis pain along the spine and frequently at the insertion of the calcaneous tendon and in the plantar fascia over the calcaneous (Gouveia *et al.* 2012).

Loss of spinal mobility is one of the principle physical findings of AS and it is often accompanied by flexion and extension restrictions in the lumbar spine area (Sieper *et al.* 2002). As the disease progresses, patients may experience straightening of the lumbar curve, atrophy of the buttocks, deepening of the thoracic curve, and destructive osteo-pathologies of the shoulders and hips that may result in flexion difficulties and deformity in those areas. Patients with advanced AS may also experience straightening of the cervical curve that causes the head to project anteriorly, making expansion of the chest difficult; vital capacity may decrease and functional residual capacity may increase (Gouveia *et al.* 2012, Sieper *et al.* 2002).

Four percent of AS patients are diagnosed with juvenile onset AS before the age of fifteen years. Patients in this small subset typically experience more frequent AS involvement in peripheral joints and more extensive hip involvement. There is a higher percentage of hip replacements in the juvenile onset group; eighteen percent of this group eventually has hip replacement surgery compared with eight percent for adult onset patients (Sieper *et al.* 2002).

Pathogenesis

At the cellular level, subchondral bone tissues in areas affected with AS are infiltrated with plasma cells, mast cells, lymphocytes, chondrocytes, and macrophages (Sieper *et al.* 2002). The affected joints typically exhibit irregular erosion and sclerosis and the joint tissue is gradually replaced by fibrocartilage and eventually ossifies. When this happens in the spine, the result is irreversible damage to the junction of the *annulus fibrosis* of the intervertebral disc and the bony margin of the vertebrae. The exterior fibers of the *annulus fibrosis* are replaced by bone and the vertebrae fuse (Sieper *et al.* 2002).

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Inflammation of the enthesis is the characteristic finding of AS. The enthesis encompasses the inserted structure (tendon, ligament, capsule or fascia) and the bone to which it is attached (Sieper *et al.* 2002). The major area affected by AS is believed to be the fibrocartilage of the enthesis and the predominant mode of ankylosing (fusion) is chondral fusion (Sieper *et al.* 2002).

Uveitis in AS

Anterior uveitis (AUU) is the most common extra-articular manifestation of AS (Gouveia *et al.* 2012).

The uvea is the middle layer of the eye. It is comprised of the iris, the ciliary body, and the choroid. The specific type of uveitis is distinguished by the part of the eye that is inflamed. For example, anterior uveitis is an inflammation of the anterior region of the eye that involves the iris. This type of uveitis is also known as iritis. Cyclitis affects the ciliary body and is known as intermediate uveitis. Choroiditis and retinitis constitute posterior uveitis and diffuse uveitis describes an inflammation of all the layers of the uvea (Mayo Clinic 2018). In any of these conditions, the vitreous humor can become inflamed and infiltrated with leukocytes, often called floaters.

Symptoms of AUU include pain, photophobia, blurred vision and uncontrolled tearing. If left untreated, uveitis can lead to glaucoma, damage to the optic nerve, cataract formation, detached retina, and loss of vision (Gouveia *et al.* 2012).

Cardiovascular involvements in AS

Patients with AS can develop cardiovascular disorders that range from asymptomatic to life threatening; all are related to inflammation (Palazzi *et al.* 2008).

Aoritis

Inflammation of the aorta (aoritis) is the most common cardiovascular involvement associated with AS and it is a potentially life-threatening complication of the disease. Aoritis characteristically involves the inflammation of the aortic root and the ascending aorta, a condition that potentially leads to valvular insufficiency. If the inflammatory process continues to the interventricular septum, the result can be conduction abnormalities of the heart (Palazzi *et al.* 2008, Palazzi *et al.* 2010).

Aortic valve disease

Aortic valve disease (AVD) that is associated with AS usually occurs alone, without stenosis or aortic insufficiency (Palazzi *et al.* 2008, Palazzi *et al.* 2010). In AVD, the aortic fibrous ring is dilated, the cusps of the aortic valve are thickened, and the free edges of the aortic valve are rolled backward. Histological examination of the aortic valve reveals a proliferation of the cells of *tunica intima*, infiltration of the *tunica media* with lymphocytes and plasma cells, destruction of the elastic fibers of *tunica media*, and fibrotic thickening of the *tunica adventitia* (Palazzi *et al.* 2008, Palazzi *et al.* 2010). Fibrotic changes are widespread and can affect the entire cusp. *Vasa vasorum* of the aorta are typically narrowed by inflammatory processes and surrounded by lymphocytes and plasma cells. If fibrosis extends from the aorta to the left atrium, it can cause mitral valve regurgitation (Palazzi *et al.* 2008, Palazzi *et al.* 2010).

The most frequent course of AS-related AVD is a slow progression of symptoms leading to valvular regurgitation and aortic insufficiency (Palazzi *et al.* 2008, Palazzi *et al.* 2010). AS patients have a 60% higher chance of being hospitalized with AVD when compared to the general population (Nurmohamed *et al.* 2012).

Conduction disturbances and A-V blocks

The second most common cardiac diseases associated with AS are conduction disturbances and A-V blocks (Palazzi *et al.* 2008, Palazzi *et al.* 2010). Conduction disorders are estimated to affect three to nine percent of AS patients. The incidence of occurrence increases with the duration of the disease (Palazzi *et al.* 2008). First, second, and third degree A-V blocks are most commonly observed in AS patients but intraventricular blocks and bradycardia or pauses related to S-A node involvement have also been reported (Palazzi *et al.* 2008).

The most likely causes of AS-related conduction abnormalities are (1) inflammatory and fibrotic lesions extending from the aorta to the interventricular septum and (2) narrowing of the S-A node artery and the A-V node artery by inflammatory processes (Palazzi *et al.* 2008, Palazzi *et al.* 2010).

Periaortitis

Periaortitis, which includes retroperitoneal fibrosis (RPE), inflammatory abdominal aneurysms (IAAA), and perianeurysmal retroperitoneal fibrosis (PRF) (a combination of the first two disorders), may also occur in AS patients (Palazzi *et al.* 2008, Palazzi *et al.* 2010).

Inflammatory Bowel Disease in AS

The number of symbiotic, commensal and pathogenic microorganisms inside of us is approximately ten times greater than the total number of our own cells (Costello *et al.* 2013). The organisms themselves, believed to number approximately 100 trillion, are known as the microbiota and the combined genetic code of the all of the organisms is known as the microbiome (Smith 2014). Microbiota populate the gut, the skin, the mouth, and the vagina but the gastrointestinal tract is the primary site where microorganisms and the immune system interact (Costello *et al.* 2013). The microbiome and the immune system constantly influence each other in that the immune system programs the quantity and constituents of the microbiota and the microbiome in turn educates the immune system and sets the immune tone (Costello *et al.* 2013, Smith 2014).

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A subset of five to ten percent of AS patients develops Inflammatory Bowel Disease (IBD) and 70% of AS patients experience subclinical bowel inflammation (Costello *et al.* 2013). AS patients and their first-degree relatives are known to have increased gut permeability, and as a result, perhaps greater systemic exposure to intestinal microbes such as *Klebsiella, Chlamydia, Campylobacter, and Shigella*. It is possible that prolonged exposure to intestinal bacteria could trigger a systemic immune response that could lead to the spread of systemic inflammation and exacerbation of the symptoms of AS (Gouveia *et al.* 2012, Smith 2014).

Speculation that gut bacteria may have an effect on AS is supported by studies using an HLA-B27 transgenic rat model. These studies have revealed that in a controlled germ-free environment, HLA-B27 transgenic rats do not get AS-like disease, while the introduction of gut bacteria into these germ-free populations results in expression of the disease (Costello *et al.* 2013, Gouveia *et al. 2012,* Smith 2014*)*.

The study of the microbiota and the microbiome in experimental animals and in AS patients is very new. Perhaps when more is known about the microbiome in AS patients, it will provide greater insight into the disease and its pathogenesis.

***Cauda equina* syndrome**

Neurological complications are rare in patients with AS. They can include solitary lumbosacral or thoracic nerve root lesions, spinal cord compression secondary to subluxation (misalignment) of the vertebrae at the atlantoaxial joint, injury to the spinal cord that can result from even minor trauma to the rigid vertebral column, and *cauda equina* syndrome (Mitchell *et al.* 1990, Sant and O'Connell 1995).

Cauda equina syndrome, first described in 1961, is a rare disorder that occurs when the roots of spinal nerves in the lower lumbar region of the vertebral canal are compressed. The condition may require emergency surgery to prevent incontinence and paralysis of the lower extremities (Mitchell *et al.* 1990, Sant and O'Connell 1995). The lesion typically affects multiple spinal nerve roots and results in bilateral loss of sensation in lower lumbar and sacral dermatomes. Muscles innervated by the damaged nerve roots atrophy and reflexes at the ankle are diminished. The symptoms of *cauda equina* syndrome include low back and lower extremity pain, sensory deficiencies in these regions, incontinence, and impotence (Mitchell *et al.* 1990, Sant and O'Connell 1995). A rare and late complication of AS, c*auda equina* syndrome is typically seen only in patients with long-standing, clinically inactive, disease who have a mean duration of the disease of 25 years (Mitchell *et al.* 1990, Sant and O'Connell 1995).

C*auda equina* syndrome is characterized by a widening of the *dura mater* that surrounds the posterior cord and the *cauda equina*, erosion of the laminae and pedicles of L_3 and L_4, and the presence of numerous posterior arachnoid diverticula. The arachnoid diverticula may extend into erosions of the lamina, pedicles, and spinous processes of the lumbar vertebrae and into the nerve roots of the *cauda equina* (Mitchell *et al.* 1990, Sant and O'Connell 1995). Bony erosions may occur at multiple levels of the vertebral column or be confined to a single level and they may be unilateral or bilateral (Sant and O'Connell 1995).

In the pathogenesis of the *cauda equina* syndrome, it is believed that the primary inflammation of the entheses associated with the vertebral column leads to secondary inflammation of the spinal meninges and bony elements of the posterior surface of the vertebral column. Nerve roots are injured as the inflammation progresses. This is likely a complex process and the mechanism by which it takes place is not currently understood (Sant and O'Connell 1995).

Current Treatment Options for Patients with AS

Four types of medications are currently available for the treatment of AS: NSAIDs, steroids, DMARDs (disease modifying anti-rheumatic drugs) and biologics.

The first line of treatment for patients with AS typically consists of NSAIDs such as ibuprofen (Advil and Motrin) and naproxen (Aleve) (Gouveia *et al.* 2012). Patients who do not respond to NSAIDs may experience a lessening of symptoms from treatment with steroids or DMARDs such as methotrexate. Patients who do not respond to any of these treatments may be treated with anti-tumor necrosis factor alpha (anti-TNF-α) drugs that are classified as biologics, the best known of which are Humira (adalimumab), Remicade (infliximab), and Enbrel (etanercept) (Enbrel Medication Guide 2018).

NSAIDs treat the inflammation associated with AS but they do not treat the disease process. Steroids suppress the body's immune response to disease but do not slow the progression of the disease. DMARDs are anti-rheumatic drugs that appear to slow the progression of the disease for some people. Most DMARDs suppress the immune responses of B and T lymphocytes and monocytes. Some, such as methotrexate, also alter phagocytosis, others affect the proliferation of fibroblasts, and some inhibit the production of cytokines (Harth 1992). The therapeutic effects of DMARDs are complex and their efficacy may vary significantly from patient to patient for reasons that are currently unknown (Harth 1992). Biologics, such as anti-TNF-α drugs, are proteins that are made in the laboratory from living tissue. Most are monoclonal antibodies that are specifically designed to suppress tumor necrosis factor alpha (TNF-α), which is an important part of the inflammatory response (Maxwell *et al.* 2015).

People who have AS overproduce the proteins that cause inflammation, particularly TNF-α. The resulting inflammation is associated with pain and swelling of the joints. Anti-TNF-α

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preparations block TNF-α, which may improve the pain and inflammation associated with the disease but also suppresses the immune system (Maxwell *et al.* 2015). Possible side effects associated with the use of anti-TNF-α drugs are related to suppression of the immune system and may include serious infections such as tuberculosis, and rarely, certain types of cancer such as lymphoma (Maxwell *et al.* 2015).

There is conflicting evidence related to the efficacy of treatment with anti-TNF-α drugs (Saad *et al.* 2010). Saad *et al.* (2010) found that patients (n = 596) taking etanercept (n = 333), infliximab (n = 171) or adalimumab (n = 92) typically experienced a 25-40% improvement in pain and inflammation; varying according to which medication they were taking. Evidence of partial remission was reported in 10-40% of the patients in this study and return to physical function was reported in 11-21% of patients. Improvement in spinal inflammation, as measured by magnetic resonance imagine (MRI), was reported in only three to six percent of patients (Saad *et al.* 2010). Clearly there are many patients who do not respond to treatment with anti-TNF-α medications. It is because of this that novel research is being directed beyond anti-TNF-α drugs to find another treatment option for AS.

Novel research

Background

The pathological process of AS can be divided into three stages:

1. Inflammation, in which tumor necrosis factor (TNF-α) is the principal cytokine (signaling molecule) involved.
2. Erosion of the affected bone.
3. Abnormal bone growth, including the formation of syndesmophytes, which are the hallmark of AS (Xie 2016).

It is not yet known whether inflammation and abnormal bone growth are linked or if they are entirely separate events (Xie *et al.* 2016).

New evidence suggests that anti-TNF-α treatment agents may suppress the immune system and relieve pain through anti-inflammatory activity, but they may not alter the progression of abnormal bone growth and bone fusion in the majority of patients with AS. Other evidence suggests that ankylosis may progress in spite of concomitant treatment with anti-TNF-α agents (Xie *et al.* 2016). Several studies have demonstrated that the Wnt signaling pathway and a decrease in natural Wnt inhibitors, such as DKK-1 (a protein associated with osteolysis) and sclerostin (a glycoprotein produced by osteocytes), are involved in abnormal bone growth and may contribute to the progression of AS (Xie *et al.* 2016).

The Wnt family consists of a number of small, cysteine-rich glycoproteins that are involved in the regulation of a variety of cellular activities, especially during development (Xie *et al.* 2016). Wnt proteins trigger signaling pathways in cells that proceed through a series of protein complexes, including the protein known as β-catenin. β-catenin functions as an intracellular signal transducer in the Wnt signaling pathway. The canonical Wnt signaling pathway regulates the expression and cellular location of β-catenin. In the absence of Wnt signaling, the level of β-catenin in the cytoplasm remains constant since β-catenin is targeted for degradation through a process of phosphorlation (Xie *et al.* 2016). Signaling from Wnt proteins prevents the phosphorlation of β-catenin and its subsequent degradation, allowing it to accumulate in the cytoplasm and ultimately enter the nucleus where it interacts with transcription factors to turn on osteogenic genes (Xie *et al.* 2016).

The Wnt proteins are critically important in normal bone homeostasis, specifically in the formation of new bone and maintaining bone mass, so it seems likely that Wnt proteins may also play a role in the process of new bone formation in AS (Dong *et al.* 2017). Recent studies have suggested that Wnt signaling is increased in AS patients (Dong *et al.* 2017). Inhibition of the Wnt signaling pathway should result in slowing or possibly stopping the growth of new bone. The most studied Wnt inhibitors are the dickkopfs (DKKs) and sclerostin. Current research seeks to determine if they play a role in the process of ankylosis in AS and whether they could be used in future therapeutic treatment of AS (Xie *et al.* 2015).

To date, there are no available treatment methods to address the progressive bone formation characteristic of AS. The bone regulating Wnt/β-Catenin signaling pathway has been shown to be up-regulated in both human and animal model studies of AS as a result of compromised levels of regulatory intermediates such as Dickkopf- 1 (DKK-1) and sclerostin (SOST). This up-regulation may account for the excessive bone formation seen in AS (Haynes *et al.* 2015). Therefore, targeting the Wnt/β-Catenin signaling pathway through increasing the levels of regulatory proteins may provide a potential therapeutic tool for the treatment of AS.

Direct injection of sclerostin

Haynes *et al*. (2015) investigated the viability of a treatment using a recombinant form of sclerostin (rSOST) protein in the disease progression of a proteoglycan-induced spondylitis (PGISp) mouse model. This is currently the only study that explores the direct injection of rSOST in treatment of AS in mice (Haynes *et al.* 2015). While rSOST treatment in this study had no affect on disease progression and severity in the peripheral or axial skeletal joints, showed no differences in bone mineral density (BMD), and showed no differences in histological scoring between the control and treated groups, there were some novel observations following the results of eight weeks of one/day rSOST injections. Notably, the study demonstrated the stability of rSOST injections in vivo (Haynes *et al.* 2015). ELISA analysis of serum collected from IL4–/– mice injected with rSOST depicted slow/minimal degradation and a sharp increase in circulating levels of rSOST at eight

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hours post injection. Levels of rSOST remained elevated for 24 hours and the bioavailability of rSOST remained high throughout the eight-week experimental period (Haynes *et al*. 2015). This suggests that the direct injection of sclerostin might be a viable option in the treatment of AS if future research establishes the efficacy of this treatment in other experimental models.

Sclerostin applied directly to osteoblasts

Treatment with recombinant sclerostin demonstrated novel effects in a study conducted by Wu *et al*. (2017). To determine the role of the increased levels of SOST observed in Type 2 diabetes mellitus, a condition that includes decreased bone mineral density and increased bone fracture risk, recombinant human sclerostin was applied directly to osteoblast cell cultures. This treatment resulted in a significant down-regulation of bone formation/remodeling biomarkers by way of the Wnt/β-Catenin signaling pathway (Wu *et al*. 2017). The down-regulation of bone formation biomarkers was coupled with an increase in phosphorylated β-Catenin, which was marked for degradation in these cells. The increase in phosphorylated β-Catenin ultimately decreases the expression of Wnt signaling target genes that favor bone production (Wu *et al*. 2017). By targeting rSOST treatment directly to bones, this therapeutic method could potentially slow or halt the progression of abnormal bone formation seen in AS by increasing the inhibition of the Wnt/β-Catenin signaling pathway.

Chrysanthemum extract to inhibit the Wnt/β-Catenin signaling pathway

Chrysanthemum idicum is known as a potent anti-inflammatory substance in homeopathic medicine. Three essential oils, all with antimicrobial properties, can be distilled from it: camphor, borneol and bornyl acetate, and 1,8-cineole (Shunying *et al.* 2005). Dong *et al*. (2017) investigated the feasibility of altering Wnt regulatory proteins with chrysanthemum extract in a proteoglycan-induced spondylitis (PGISp) mouse model of AS. Their study centered on disease progression and the severity of the disease and specifically evaluated the effects of *Chrysanthemum idicum* on the Wnt signaling pathway, antioxidative enzymes, and proinflammatory cytokines (Dong *et al.* 2017).

In this study, peripheral disease progression appeared to be significantly impeded in mice that were given dietary *Chrysanthemum indicum* extract compared to the control mice. This was demonstrated by the presence of arthritic markers and a notable difference in observed disease severity in stained vertebral samples of experimental mice as compared to the control group (Dong *et al*. 2017). Western Blot analysis revealed significantly higher levels of both SOST and DKK-1 in the experimental mice compared to the control group, indicating an overall increase in Wnt signaling antagonists that are under-expressed in AS (Dong *et a*l. 2017).

The findings of this study suggest that *Chrysanthemum indicum* extract helps to alleviate inflammation and oxidative stress and increase the concentrations of DKK-1 and SOST, which inhibit the Wnt cascade (Doug *et al.* 2017). The changes in the progression of AS in the mouse model were likely due to modulations in the regulation of the Wnt/β-Catenin signaling pathway that resulted from *Chrysanthemum indicum* extract supplementation. The inhibition of the Wnt/β-Catenin signaling pathway resulted in the decrease in the progression of AS and the subsequent decrease in excessive bone formation in the experimental mice. This study supports the possible therapeutic effects of SOST and DKK-1 in combating the progression of AS to the osteoproliferatory phase. Further research is needed to more fully understand the beneficial role of *Chrysanthemum idicum* in the treatment of AS.

Chrysanthemum morifolium ameliorates ulcerative colitis in a rat model

In a study using chrysanthemum extract, Tao *et al.* (2017) investigated the effect of *Chrysanthemum morifolium* polysaccharides on the microbiota of rats with experimentally induced inflammatory bowel disease in an ulcerative colitis rat model in which the intestinal flora are known to change significantly. In this study, the tendency of the microbiota to change with the progression of ulcerative colitis was markedly reduced and healthy microbial diversity was partially restored after oral treatment with chrysanthemum polysaccharides. This raises the intriguing possibility of further research to investigate whether the increased levels of SOST and DKK-1 in the Dong *et al.* (2017) study (see above) were related to alterations in the microbiota and whether the microbiome characteristic of AS might be normalized by treatment with *Chrysanthemum morifolium* polysaccharides (Tao 2017).

Conclusion

AS is an autoimmune disease that is characterized by inflammation, bone erosion, and new bone formation. It can also affect the eyes, the cardiovascular system and the bowel. The use of anti-inflammatory cytokines, such as TNF-α inhibitors, initially touted as one of the greatest advances in the treatment of AS over the past 20 years, treat the symptoms of the disease but do not appear to halt the formation of new bone and the progression of the disease in the majority of patients.

At the present time, there is no known treatment for the progressive osteoproliferatory phase of AS. The Wnt/β-Catenin signaling pathway plays a crucial role in normal bone development and bone homeostasis. It is an area of intense study in trying to address the excessive bone formation associated with AS by suppressing the production of β-Catenin and increasing the concentration of Wnt inhibitors DKK-1 and sclerostin. A better understanding of the relationships among Wnt signaling, the formation of syndesmophytes, and the process of ankylosis in AS will hopefully shed light on the

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pathogenesis of this disease and facilitate the development of new treatment options.

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Literature cited

Benjamin M and D. McGonagle (2001) The anatomical basis for disease localisation in seronegative spondyloarthropathy at entheses and related sites. *J. Anat.* 199:503-526.

Bluestein, Harry G (1988) Anatomic and genetic considerations in the pathogenosis of ankylosing spondylitis. *The Journal of rheumatoloty. Supplement* 16, Vol. 15: 29-32

Braun J, X Baraliakos, W Golder, K-G Hermann, J Listing, J Brandt, M Rudwaleit,
S Zuehlsdorf, M Bollow, J Sieper, D van der Heijde (2004) Analysing chronic spinal changes in ankylosing spondylitis: a systematic comparison of conventional x rays with magnetic resonance imaging using established and new scoring systems. *Ann Rheum Dis*. 63:1046-1055. doi: 10.1136/ard.2003.019968

Costello MA, Elewaut D, Kenna TJ, Brown MA (2013) Microbes, the gut and ankylosing spondylitis. *Arthritis Res Ther.* 1364:25-31. doi: 10.1111/nyas.12968

Dong M, Yu D, Duraipandiyan V, Abdullah Al-Dhabi N (2017) The Protective Effect of Chrysanthemum indicum Extract against Ankylosing Spondylitis in Mouse Models. *BioMed Research International*. Vol 2017. ID 8206281 p.1-7. doi.org/10.1155/2017/8206281

ENBREL Package Insert. Retrieved 6/28/2018 via link from Pharmacists' Letter. file:///C:/Users/User/Downloads/231396.841.pdf

Gouveia, Enéias Bezerra, Dório Elmann, Maira Saad de Ávila Morales (2012) Ankylosing spondylitis and uveitis: overview. *Rev Bras Reumatol* 52(5):742-756.

Harth M (1992) Mechanisms of action of disease modifying antirheumatic drugs.
J Rheumatol Suppl. 32:100-3.

Haynes KR, Pettit AR, Duan R, Tseng H, Glant TT, Brown MA, Thomas GP (2012) Excessive bone formation in a mouse model of ankylosing spondylitis is associated with decreases in Wnt pathway inhibitors. *Arthritis Research & Therapy*.*14*(6) R253.

Haynes KR, Tseng H, Kneissel M, Glant TT, Brown MA, Thomas GP (2015) Treatment of a mouse model of ankylosing spondylitis with exogenous sclerostin has no effect on disease progression. *BMC Musculoskeletal Disorders*. (26)16: 368.
doi: 10.1186/s12891-015-0823-8.

Mayo Clinic (2018) Uveitis
https://www.mayoclinic.org/diseases-conditions/uveitis/symptoms-causes/syc-20378734
Accessed June 4, 2018.

Maxwell LJ, Zochling J, Boonen A, Singh JA, Veras MMS, Tanjong Ghogomu E, Benkhalti Jandu M, Tugwell P, Wells GA (2015) TNF-alpha inhibitors for ankylosing spondylitis. Cochrane Database of Systematic Reviews 2015, Issue 4. Art. No.: CD005468 Copyright © 2015 The Cochrane Collaboration. Published by John Wiley & Sons, Ltd doi: 10.1002/14651858.CD005468.

Mitchell MJ, Satoris DJ, Moody D, Resnick D (1990) Cauda Equina Syndrome Complicating Ankylsoing Spondylitis. *Radiology*. 175: 521-525.

Nurmohamed MT, van der Horst-Bruinsma I, Maksymowych WP (2012) Cardiovascular and Cerebrovascular Diseases in Ankylosing Spondylitis: Current Insights. *Curr Rheumatol Rep*.14:415–421. DOI 10.1007/s11926-012-0270-6

Palazzi C, D'Angelo S, Lubrano E, Olivieri I (2008) Aortic involvement in ankylosing spondylitis. *Clin Exp Rheumatol.* 26 (Suppl. 49): S132-S135.

Palazzi C, Carlo Salvarani, Salvatore D'Angelo, Ignazio Olivieri (2010) Aortitis and periaortitis in ankylosing spondylitis. *Joint Bone Spine* 78: 451–455. doi:10.1016/j.jbspin.2010.11.003

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Saad, Amr A, Darren M. Ashcroft, Kath D Watson, Deborah PM Symmons, Peter R Noyce, Kimme L Hyrich, on behalf of the BSRBR (2010) Efficacy and safety of anti-TNF therapies in psoriatic arthritis: an observational study from the British Society for Rheumatology Biologics Register, *Rheumatology*. 49(4): 697-705. https://doi.org/10.1093/rheumatology/kep423

Sant SM, and O'Connell D (1995) Cauda Equina Syndrome in Ankylosing Spondylitis: A Case Report and Review of the Literature. *Clinical rheumatology* 14(2): 224-226.

Sieper J, J Braun, M Rudwaleit, A Boonen, A Zink (2002) Ankylosing spondylitis: an overview. *Ann Rheum Dis* **61**(Suppl III):iii8–iii18

Smith JA (2015) Update on ankylosing spondylitis:current concepts in pathogenesis. *Curr Allergy Asthma Rep*. 15:489-498. DOI 10.1007/s11882-014-0489-6

Shunying Z, Yang Y, Huaidong Y, Yue Y, Guolin Z (2005) Chemical composition and antimicrobial activity of the essential oils of Chrysanthemum indicum.

J Ethnopharmacol. 96(1-2):151-8. DOI:10.1016/j.jep.2004.08.031

Tao Jin-Hua, Duan JA, Jiang S, Fenf NN, Qui WG, Ling L (2017) Polysaccharids from Chrysanthemum morifolium Ramat ameliorate colitis rats by modulating microbiota community. *Oncotarget*. 8(46):80790-80803. doi: 10.18632/oncotarget.20477

Wu Y, Xu SY, Liu SY, Xu L, Deng SY, He YB, … Ni GX (2017) Upregulated serum sclerostin level in the T2DM patients with femur fracture inhibits the expression of bone formation/remodeling-associated biomarkers via antagonizing Wnt signaling. *European Review for Medical and Pharmacological Sciences*. *21*(3): 470-478.

Xie,W, Zhou L, Li S, Hui T, Chen D (2015) Wnt/β-catenin signaling plays a key role in the development of spondyloarthritis. *Ann NY Acad Sci*. 1364:25-31.
doi: 10.1111/nyas.12968.

Xie, Wanqing Xie, Lijiang Zhou, Shan Li, Tianqian Hui and Di Chen (2016) Wnt/β-catenin signaling plays a key role in the development of spondyloarthritis. *Ann NY Acad Sci* 1364(1): 25–31. doi: 10.1111/nyas.12968

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Alphabet Soup of Active Learning: Comparison of PBL, CBL, and TBL

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Abstract
Faculty in higher education strive to prepare students who have mastered discipline specific content, are adept at using "soft skills" required in the workplace, and have the ability and motivation to pursue life-long learning. A variety of methods including problem, case, and team-based learning have been developed to achieve these outcomes. These three approaches have similar acronyms, share common elements, and have been vastly modified to achieve various outcomes. As a result, a great deal of confusion has arisen. The aim of this paper is to provide clarity by contrasting and comparing these three methods. Additionally, brief reports from the literature will be discussed, as well as guidance for use of each method. Faculty are encouraged to choose methods that are best suited to the characteristics of their students and their own personal skill-set and preferences. Furthermore, faculty are encouraged to follow best practice in establishing clear objectives, assessing outcomes, and sharing successes and failures through publication. This article contrasts and compares problem-based (PRL), case-based (CBL), and team-based learning (TBL). https://doi.org/10.21692/haps.2018.019

Key words: problem-based, case-based, team-based, small group, collaborative learning

Introduction
Faculty in higher education have been called to modify our methods and utilize strategies to more fully engage our students. Desired outcomes include preparing students who have mastered discipline specific content, are adept at using "soft skills" required in the workplace, and have the ability and motivation to pursue life-long learning. Over time, a variety of methods have been developed to achieve these outcomes. Three commonly utilized methods include: problem-based learning (PBL), case-based learning (CBL), and team-based learning (TBL). These three approaches have similar acronyms, share common elements, and have been represented in the literature with vast variety of modification. As a result, a great deal of confusion has arisen, and faculty often have misperceptions concerning implementation.

To provide clarity, the objectives of this paper are to:

1. Describe the history and aims for each method.
2. Contrast and compare essential elements of each method.
3. Share a sampling of reports from the literature addressing use of each method.

Problem Based Learning (PBL)
Problem-based learning was first developed for use in medical education by Howard Barrows in the late 1960s (Barrows 1986). Barrows developed this method for use with students at McMaster University Medical School with hopes of making medical education more interesting and relevant for his students. The primary aim of this method was to incorporate patient and community health problems in the instructional delivery. According to Barrows (1986), the objectives of PBL include:

1. Structuring knowledge for use in clinical contexts.
2. Developing effective clinical reasoning process.
3. Developing effective self-directed learning skills.
4. Increasing the motivation for learning.

Barrows gleaned ideas from the work of others (Cabot 1906) and developed PBL to prepare his students for their clinical training. Although we now recognize that this method relies on constructivist thinking, Barrows had no background in educational psychology or cognitive science. PBL has a number of theoretical underpinnings from the psychology literature and has previously been referred to as discovery learning, enquiry learning, experiential learning, and constructivist learning.

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PBL sessions involve small groups of four to eight students working together to confront "real world" problems often presented as clinical cases (Table 1). Cases are presented during the first of several sessions, and students are not required to prepare prior to the session. This mode of instruction is considered open inquiry, as there is not a correct answer for the case. After receiving case information, students organize their prior knowledge and attempt to identify the nature and scope of the problem. Students pose questions about what they do not understand, and utilize a self-directed learning approach to seek answers to their questions. Students are expected to learn from one another and from learning resources identified by the students themselves. Students are typically left on their own to conduct their research, and faculty intervention is minimal. PBL sessions often run over the course of several days or sessions, and additional information may be added to the case in each subsequent session. After gathering the appropriate resources and conducting their research, students collaborate within their group to organize their case solutions and present their work. Groups may offer differing resolutions and recommendations and should be prepared to elaborate on their decisions. During the case presentation, students respond to questions posed by peers and facilitators. Ideally, the entire class reaches consensus as to the "best case" solution for the problem.

Table 1. Characteristics of PBL, CBL and TBL

Characteristic	PBL	CBL	TBL
Advance preparation	No advance prep	Advance prep	Advance prep - IRAT
Activity	Case based	Case based	IRAT, TRAT, brief lecture & activity
Learning objectives	Written by students	Provided to students	Provided to students
Organization	Small groups (4-8 students)	Small groups (4-8 students)	Small groups (4-8 students)
Learning method	Self-directed	Shared facilitator and self-directed	Shared facilitator and self-directed
Role of faculty	Limited guidance	Active guidance	Active guidance
Inquiry style	Open inquiry	Guided or structured inquiry	Guided or structured inquiry
Number of sessions	Multiple sessions	Single session	Single session
End of session	Student presentations	Wrap-up by faculty	Wrap-up and peer evaluation

Despite little evidence that PBL was effective in preparing clinicians, the Association of Medical Colleges and World Federation of Medical Education endorsed the method and a vast body of literature addressing the use of this method has been amassed. Despite several systematic reviews and meta-analyses, divergent opinions have formed as to the effectiveness of this method (Albanese 2000, Neville 2009, Smits *et al*. 2003, Vernon and Blake 1993). It is not surprising that differing opinions exist since there are many different definitions of PBL, and its delivery has commonly been modified to achieve diverse outcomes. Although students participating in PBL sessions generally report positive attitudes, several studies report no difference in factual knowledge gained (Albanese 2000, Vernon and Blake 1993). It has also been noted that some students report feeling less prepared when participating in PBL-based curricula (Albanese 2000). In contrast, Koh and colleagues (Koh *et al*. 2008) report that PBL has positive effects on physician competency after graduation, mainly in social and cognitive dimensions. Similarly, others generally agree the PBL enhances professional competency (Neville 2009, Vernon and Blake 1993).

Barrows hoped that students would acquire skill in evaluating a patient's condition, identifying the problem(s), and making appropriate clinical decisions to manage the patient's care. Some PBL supporters contend that this method is most successful when utilized with more advanced students. In the strictest sense, this method requires the student to self-identify and address learning gaps. Early in the students' academic career they may not be developmentally ready, or possess the basic foundational knowledge to be able to do this within a clinical context. Relying on this method too early in the students' academic career may have negative outcomes. It is possible that that this method places too much load on working memory. There is evidence that working memory cannot problem solve and learn at the same time (Kirschner *et al*. 2006). It is also likely that the process of learning how to practice medicine and actually practicing are cognitively very different (Kirschner *et al*. 2006, Neville 2009).

Although PBL has continued to be a common methodology utilized in medical education, its limitations have been noted. Shortcomings of PBL have been addressed in the development of similar, yet distinctly different approaches including case-based learning (CBL).

Case Based Learning (CBL)

Although CBL was first described in 1912 by Lorrain Smith at the University of Edinburgh, and adopted by Harvard Business School in the 1920s, its instructional use in the areas of health and medicine did not become commonplace until the 1990s.

PBL and CBL share common objectives, and both rely on collaborative learning as students work in small groups (Table 1). Case-based learning differs from PBL in that it requires students to develop a knowledge base prior to exposure to case-based problems. CBL attempts to link basic scientific understanding (commonly delivered via lecture) to future clinical practice. Typically, students are expected to

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complete readings or assignments prior to the CBL session, and learning objectives are clearly communicated before the session begins. During CBL sessions, faculty take a more active role and interact with students to provide feedback, answer questions, guide discussion and direct progress. When learners explore tangents, facilitators use guiding questions to bring them back to the learning objectives. During the session, students are encouraged to ask questions, and facilitators actively engage in correcting incorrect assumptions of the learner. Students are directed to specific learning resources, but are also encouraged to seek additional resources as needed. With CBL, the facilitator shares with students the "best possible" or correct solution as part of a wrap-up near the end of the session. Typically, CBL is delivered via a single working session and students are not assigned follow-up work or group presentations.

Similar to PBL, CBL has a large body of work describing its use and effectiveness. It is most commonly reported that students and faculty enjoy CBL and think it enhances learning and motivation (Thistlethwaite *et al.* 2012). However, at least one study reported a negative student attitude as students did not believe CBL prepared them well for exams (Blewett and Kisamore 2009). In other reports, students share dissatisfaction due to the adverse amount of time required and the resulting workload.

When limiting review of literature to health professions, a systematic review including 104 independent studies concluded there is insufficient evidence to support perceptions of enhanced learning (Thistlethwaite *et al*. 2012). Although students self-report increased confidence, communication skills, beneficial interaction between classmates, clinical reasoning and decision making, there is little empirical or objective evidence provided. When objective measures are made, there are conflicting results (Thistlethwaite *et al.* 2012). For example, in specific educational settings, CBL is associated with higher exam scores (Cliff and Wright 1996, Dupuis and Persky 2008), no difference in exam scores (Gemmell 2007), and even a lowering of exam scores (Thistlethwaite *et al.* 2012).

Many factors likely play a role in explaining the diversity of results reported in the literature. There has been a wide range in the type, timing, number, and length of student exposure to cases as well as in the instructor's level of training and experience in facilitating case studies. In some instances, students were exposed to single CBL sessions while other programs adopted entire courses or curricula embracing CBL methodology. Group sizes also varied greatly with some students working independently and other groups including 30 or more students (Thistlethwaite *et al.* 2012). Furthermore, there is evidence that sessions may be more beneficial when led by a content expert rather than a non-expert (Hay and Katsikitis 2001). It has also been suggested that faculty trained in facilitation skills will likely be better facilitators. Of interest is the fact that female students may perform better than men in a case-based learning environment (Williams 2005) and higher performing students demonstrate no differences in knowledge related to method of learning (Koles *et al.* 2005). When directly comparing CBL to PBL, two California medical schools administered a 24 item survey and discovered that 89% of the students and 84% of faculty favored CBL over PBL (Srinivasan *et al.* 2007). Students indicated fewer unfocused tangents, less busy-work, and more opportunities for clinical skills application when modules were presented in CBL format. Students were frustrated by PBL due to perceived lack of closure (no correct answer), additional work between sessions, tangential exploration of topics, and lack of direction in developing case presentations. Students also note that student PBL presentations were often inaccurate or incomplete when considering the complexity of the problem. These findings indicate that PBL may be better suited for more advanced learners who already have context for solving the PBL problem and have greater mastery in self-directed research and learning. Faculty comments were similar to students. Faculty were particularly concerned with PBL as they felt they should provide direction and feedback when students were unskilled. It was also interesting that ten to fifteen percent of students surveyed were persistently unhappy with small group work of either type.

Team based learning (TBL)

Most researchers credit Larry Michaelsen for first describing TBL in the early 1980s (Michaelsen *et al.* 1982). Since then, TBL has become popular for use in health and medical education. This method emphasizes student preparation prior to class, application of knowledge in class, and development of effective small group dynamics (Table1). Similar to PBL and CBL, TBL may rely on cases to engage students in using course content to solve problems likely to be encountered in future practice. However, TBL activities are not limited to cases and can incorporate a variety of problems. TBL, more so than CBL, places emphasis on assuring students have mastered course content before entering the problem solving stage of the session (Michaelsen and Sweet 2008).

Prior to a TBL session, students are expected to read and study the materials provided in preparation for a series of "readiness" activities (Table 2). The first step in a TBL session is a short quiz referred to as the Individual Readiness Assurance Test (IRAT). The IRAT evaluates understanding of key items from the pre-session assignments, and is intended to motivate the student to study and prepare prior to the session. Following the IRAT, students work in groups to address the same set of questions, and this is termed the Team Readiness Assurance Test (TRAT), which is sometimes referred to as group readiness or GRAT). It is emphasized that students receive immediate feedback on the TRAT since feedback is essential to learning and retention of concepts (Hattie and Timperley 2007). There is also an opportunity for students to submit (in writing) an evidence-based challenge to answers. Once appeals have

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been resolved, the instructor has the opportunity to deliver a short lesson and clarify misperceptions. At this point, students are now ready to convene their groups to engage in problem solving activities. Although TBL sessions often include clinical cases, they can alternatively engage the students in other original learning activities including concept mapping, product development, or finding solutions to a problem set. Whatever the task, small groups in TBL sessions all work on the same significant problem, are given specific choices to make, and complete the session by sharing (usually simultaneously) their choices.

Table 2. Elements of Team Based Learning

1. **Strategically formed teams**
   - Diverse permanent teams throughout unit
   - Teams progress through stages – "form, storm, norm, and perform" (Tuckman 1965)
2. **Readiness assurance**
   - Pre-class preparation (assigned readings and study)
   - iRAT – individual (individual prepares prior to class)
   - tRAT – team – peer discussion, report simultaneously
   - Written Appeals
   - Clarifying lecture
3. **Application activities that promote both critical thinking and team development**
   - Cases
   - Concept mapping
   - Product development
   - Problem set
4. **Peer evaluation**
   - Anonymous feedback

According to Michaelson and Sweet (2008), it is important to form diverse groups that are retained for the entire course. It is believed that having groups stay together provides the opportunity for groups to move through the key stages essential to developing high-performing teams: forming, storming, norming, and performing (Tuckman 1965). Additionally, strict adherence to TBL format includes peer evaluation. It is hoped students who stay in the same group for an extended period develop strong interpersonal relationships and are able to observe and share useful feedback to each other.

Similar to PBL and CBL, reports of TBL use in the literature vary as specific steps and core design elements are frequently modified (Parmelee *et al.* 2012). In a recent review of TBL use in medical education, the authors first identified a total of 147 studies, but only 14 strictly adhered to the classic TBL approach (Burgess *et al.* 2014). The authors conclude that lack of adherence to design, implementation, and reporting of TBL make it challenging to critique, replicate, and compare learning outcomes. However, individual studies do report positive student perceptions (Parmelee *et al.* 2009), improved test performance on questions aligned with TBL concepts (Koles *et al.* 2005), and improved student understanding of difficult concepts (Zgheib *et al.* 2010). Additionally, studies indicate that IRAT scores are good predictors of examination performance (Nieder *et al.* 2005) and thus have the opportunity to serve as "early alert" for students who may need additional assistance. It has also been shown that students performing in the lowest quartile demonstrate the greatest gains in exam scores when participating in TBL-based modules (Koles *et al.* 2005).

Summary

In order to more effectively prepare our students to meet the demands of the workplace, faculty have pursued creative ways to engage students addressing "real-world problems". Although PBL, CBL and TBL follow different protocols, all rely on collaborative small group work. Although working effectively as a member of a group is considered essential to the development of today's learner, this approach makes it difficult to ascertain the benefits of PBL, CBL and TBL independent of the benefits of small group collaboration. Group learning is generally highly rated, and there are problems disentangling cause and effect due to confounding factors (Curran *et al.* 2008).

As indicated throughout this report, outcomes for each method vary greatly. In all cases, the method is impacted by the fact that instructors modify the approach to meet their preferences and constraints. Although modification makes comparison and reproduction more challenging, this type of adaptability has long been encouraged in educational training.

Perhaps it is most important that faculty choose methods best suited to the characteristics of their students (level, demographics, and prior experience) and their own personal skill-set and preferences. When choosing to use PBL, CBL or TBL, faculty may be best served by using a backward design approach, which entails first determining what students are expected to know or do, and then choosing the method most likely to achieve the desired outcomes. Faculty are also encouraged to reflect on their personal abilities and preferences, and select methods of best fit. Although students often describe PBL, CBL and TBL as enjoyable, it is important to avoid a "gimmicky" approach and look for ways to promote

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deep thinking, enhance learning, drive curiosity, generate passionate life-long learning, and develop skills for success in today's work environment.

Speaking from personal experience, it can be challenging, yet enjoyable and rewarding to develop original small group learning activities. Best practice is to establish clear objectives, assess effectiveness in achieving objectives, and follow through with sharing successes and failures through publication. Know that what you are doing is working for YOU, and share with others so that they might be inspired by your ideas and insights.

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Literature cited

Albanese M (2000) Problem-based learning: why curricula are likely to show little effect on knowledge and clinical skills. *Medical education*. 34(9): 729-738.

Barrows HS (1986) A taxonomy of problem-based learning methods. *Medical education*.20(6): 481-486.

Blewett EL, and Kisamore JL (2009) Evaluation of an interactive, case-based review session in teaching medical microbiology. *BMC medical education*. 9(1): 56.

Burgess AW, McGregor DM, and Mellis CM (2014) Applying established guidelines to team-based learning programs in medical schools: a systematic review. *Academic Medicine*. 89(4): 678.

Cabot RC (1906) *Case teaching in medicine*: DC Heath & Company.

Cliff WH, and Wright AW (1996) Directed case study method for teaching human anatomy and physiology. *Advances in Physiology Education*. 270(6): S19.

Curran VR, Sharpe D, Forristall J, and Flynn K (2008) Student satisfaction and perceptions of small group process in case-based interprofessional learning. *Medical Teacher*. 30(4): 431-433.

Dupuis RE, and Persky AM (2008) Use of case-based learning in a clinical pharmacokinetics course. *American journal of pharmaceutical education*. 72(2): 29.

Gemmell HA (2007) Comparison of teaching orthopaedics using an integrated case-based curriculum and a conventional curriculum: A preliminary study. *Clinical Chiropractic*. 10(1): 36-42.

Hattie J, and Timperley H (2007) The power of feedback. *Review of educational research*. 77(1): 81-112.

Hay PJ, and Katsikitis M (2001) The 'expert' in problem-based and case-based learning: necessary or not? *Medical Education*. 35(1): 22-26.

Kirschner PA, Sweller J, and Clark RE (2006) Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational psychologist*. 41(2): 75-86.

Koh GCH, Khoo HE, Wong M, and Koh D (2008) The effects of problem-based learning during medical school on physician competency: a systematic review. *Canadian Medical Association Journal*. 178(1): 34-41.

Koles P, Nelson S, Stolfi A, Parmelee D, and DeStephen D (2005) Active learning in a year 2 pathology curriculum. *Medical education*. 39(10): 1045-1055.

Michaelsen LK, and Sweet M (2008) The essential elements of team-based learning. *New directions for teaching and learning*. 2008(116): 7-27.

Michaelsen LK, Watson W, Cragin JP, and Dee Fink L (1982) Team learning: A potential solution to the problems of large classes. *Exchange: The Organizational Behavior Teaching Journal*. 7(1): 13-22.

Neville AJ (2009) Problem-based learning and medical education forty years on. *Medical Principles and Practice*. 18(1): 1-9.

Nieder GL, Parmelee DX, Stolfi A, and Hudes PD (2005) Team-based learning in a medical gross anatomy and embryology course. *Clinical Anatomy*. 18(1): 56-63.

Parmelee DX, Michaelsen LK, Cook S, and Hudes PD (2012) Team-based learning: a practical guide: AMEE guide no. 65. *Medical teacher*, 34(5): e275-e287.

Parmelee DX, DeStephen D, and Borges NJ (2009) Medical students' attitudes about team-based learning in a pre-clinical curriculum. *Medical education online.* 14(1): 4503.

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Smits PB, D de Buisonjé C, Verbeek JH, van Dijk FJ, Met JC, and Cate OJ (2003) Problem-based learning versus lecture-based learning in postgraduate medical education. *Scandinavian journal of work, environment & health*. 280-287.

Srinivasan M, Wilkes M, Stevenson F, Nguyen T, and Slavin S (2007) Comparing problem-based learning with case-based learning: effects of a major curricular shift at two institutions. *Academic Medicine*. 82(1): 74-82.

Thistlethwaite JE, Davies D, Ekeocha S, Kidd JM, MacDougall C, Matthews P, Purkis J, and Clay D (2012) The effectiveness of case-based learning in health professional education. A BEME systematic review: BEME Guide No. 23. *Medical teacher*. 34(6): e421-e444.

Tuckman BW (1965) Developmental sequence in small groups. *Psychological bulletin*. 63(6): 384.

Vernon DT, and Blake RL (1993) Does problem-based learning work? A meta-analysis of evaluative research. *Academic medicine*. 68(7):550-563.

Williams B (2005) Case based learning—a review of the literature: is there scope for this educational paradigm in prehospital education? *Emergency Medicine Journal*. 22(8): 577-581.

Zgheib NK, Simaan JA, and Sabra R (2010) Using team-based learning to teach pharmacology to second year medical students improves student performance. *Medical teacher*. 32(2): 130-135.

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Development of an Undergraduate Course Designed to Increase Hands-On Research Opportunities for Students at Colorado State University

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Abstract
Undergraduate research experiences are valuable, yet can be difficult for students to obtain. Working on open-ended research questions enables students to develop problem-solving skills, increase communication skills, enhance critical thinking, and help define career goals. Unfortunately, some students are unable to find positions in research laboratories and miss this educational opportunity. To address this problem, the Biomedical Sciences Department at Colorado State University developed a course in 2015 that enabled students to participate in hands-on research centered on projects stemming from faculty laboratories. The information provided here describes the development and funding for this course, the likely benefits for students, and a preliminary view of student reactions to the course. Future efforts will focus on developing metrics to better evaluate student learning. https://doi.org/10.21692/haps.2018.022

Key words: critical thinking, problem solving, communication skills, surveys

Introduction
Experience with laboratory research is beneficial for undergraduate students, leading to improvements in skills related to experiment design and execution, analysis of data, communication, independent work, and career decisions (Bauer and Bennett 2003, Tan 2007). Additionally, these experiences help students with more general personal growth, including increasing confidence and awareness (Russell *et al.* 2007). Unfortunately, positions in research labs can be difficult for undergraduate students to obtain for a variety of reasons, including a lack of available positions, time and resource burdens on research faculty, and in some cases, a lack of student confidence to find and request such opportunities (Merkel 2003). To address these issues, the Biomedical Sciences Department at Colorado State University developed a course that allows undergraduate students to experience a research lab environment and work on real, open-ended research questions derived from faculty laboratories. The goal was to have students and faculty benefit from the course. Specifically, it was hoped that students would learn in-depth information about a specific research topic, go through training identical to what they would encounter as a graduate student or laboratory technician, and experience the exciting and frustrating aspects of research. In addition, students would learn how to properly keep a laboratory notebook, develop and test protocols, gather data to test hypotheses, analyze data, participate in lab meetings, and learn to communicate their research findings. The opportunity to work closely with individual faculty members was also seen as beneficial. For faculty, potential benefits were thought to include the possibility of student researchers generating useful data, testing new protocols, providing a fresh perspective, or helping to determine the feasibility of pilot projects. Identification of quality students that might want to continue working in the faculty laboratory was also a potential benefit. In addition to student and faculty gains, the undergraduate research course was expected to remove some of the burden on individual labs in the department by providing up to 20 students a year (two sections of the course with ten students per section) with research experience opportunities. Finally, the course would add to the quality of the curriculum and expand course offerings for upper division undergraduate students. We introduced this course in 2015 as an experimental course (Neuroscience Research, BMS 480) and it is now a permanent, regular course (Research in Biomedical Sciences, BMS 401) available to students each year.

The purpose of this article is to outline how the undergraduate research course was designed and funded and to provide a preliminary view of student responses to the course.

Methods
Participants
Participants were undergraduate students enrolled in BMS 480, section I (Neuroscience Research, 2015 and 2016) and BMS 401, section I (Research in Biomedical Sciences, 2017). During 2015-2016, the course was experimental and was converted to a permanent course beginning in fall 2017. All sections of the course were taught in fall semesters by the author. Another faculty member taught a section of the

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course during the spring semester, but specifics of this section will not be discussed in this article. This study was reviewed by the Institutional Review Board at Colorado State University (IRB ID: 002-19H) and was declared exempt according to 45 CFR 46.101(b).

General Course Preparation

Initial tasks included faculty meetings to determine overall goals for the course, getting approval from university curriculum committees, securing funding, obtaining space for the course and collecting equipment and furniture. Departmental staff worked with the instructors (for both the fall and spring sections) to navigate the curriculum committee approval process. During this time, it was also decided that the course would be four credits and consist of six hours of lab time and one to two hours of recitation per week. This time was split between Tuesday and Thursday to avoid conflicts with other courses. Funding for the course came from multiple sources including: the CSU Provost Office, the College of Veterinary Medicine and Biomedical Sciences, The State of Colorado, The City of Fort Collins, and Sapien LLC. The CSU funds were provided following applications for awards to increase experiential learning and a research application to the college. The remaining funds were awarded via an Office for Economic Development and International Trade award that was provided for the specific research project (see Acknowledgements for more details). Funding was used to buy equipment and supplies for experiments, purchase computer software, and to compensate the human subjects who volunteered to take part in the research study. An appropriate space for the course was found in the Physiology building at Colorado State University during the spring semester of 2015. The course was first taught in Fall 2015. The space designated for the course had previously been occupied by a research faculty member who had retired. Furniture and laboratory supplies were gathered during the spring and summer and came from retiring faculty, faculty upgrading equipment, internal funds designed to increase experiential learning, and research funding. The teaching laboratory was cleaned and set-up during the summer prior to the first fall class and IRB personnel inspected the research area prior to the first semester of the class.

Learning Management System (LMS) and Computer Software

The instructor utilized CSU's Learning Management System (LMS, Canvas) and designed and uploaded documents including initial presentations, required training details with links to online sites, initial reading materials, directions for assignments, and Standard Operating Procedures (SOPs). (For more information on SOPs, see below under Research Project Specific Preparation). A shared drive was set-up for the course to allow students and lab personnel to store data, analyses, and projects. The LMS also contained instructions for accessing the shared drive. Material was added to the LMS throughout the semester and students were expected to login each week. Software needed for data analysis included Microsoft Office, MatLab, Photoshop, Image J, and custom software designed for the sensory substitution device that was used for experiments with research subjects. Some software was installed prior to the beginning of the semester, but students were required to install some of the software as part of the course.

Research Project Specific Preparation

The research project used for this course focused on the design, development and testing of a sensory substitution device for human applications (Moritz *et al.* 2017). The overall goals for the project are to assist hearing-impaired individuals who are unable to benefit from cochlear implants or hearing aids due to neuronal damage in the auditory pathway. Sensory substitution is an approach that allows information to be sent to the brain via an alternate sensory pathway (Bach-y-Rita and Kercel 2003). A well-known example of this is the use of Braille by visually impaired individuals. The goal of our research is to get auditory information to the brain using a wireless lingual electrotactile device embedded in an orthodontic retainer. Based on previous research, a device was designed and created by the research team and students in the course used this device to determine the sensitivity and discrimination ability of participants who were recruited from the CSU community. The students also did experiments to investigate the lingual anatomy and bitter taste function of the human participants and compared these results to electrotactile perception abilities. The main goals of the project were established prior to course development and the research team included members of the Biomedical Sciences Department and the Department of Mechanical Engineering. Some of the research team was involved in running the course during the semester. The author determined the course content and structure. Because the project involved working with human participants, a course-specific IRB was written specifying that undergraduate students would be interacting with participants. This included specific SOPs for interacting with participants and was written and submitted during early summer to ensure approval process prior to the beginning of the semester. The role of undergraduate researchers was outlined in the consent form that was submitted and approved by the Institutional Review Board at CSU. Standard Operating Procedures (SOPs) for student training and equipment operation were also developed and written during the summer. All SOPs were posted on Canvas and hard copies were placed in a three-ring binder in the teaching laboratory.

Surveys

Students in the course filled out two types of surveys. One was the standard CSU course survey, consisting of 29 questions that students were asked to rate on a scale from Excellent to Poor, with the added option of Not Applicable. There was also a space available for written comments. A subset of the questions from the section "About the Course" are presented

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in the results section of this article. In 2016 and 2017, custom surveys were also created by the author and given to the students. The survey was revised in 2017, but both surveys included the following questions:

1. What are two unique features of this course relative to other courses you have taken?
2. Do you feel that you experienced "hands-on" research and are better able to make a decision about whether you would consider academic research as a career? Please explain.
3. Is there anything that you would change or add to the course to make it better?

In addition, the 2017 survey included the following questions:

4. We did two different presentations in the course. What did you learn from doing these? Do you feel more confident about your ability to talk about research projects after the presentations?
5. In some cases, it was required that you and/or your group figure out how to address a technical issue and/or figure out how to do specific analyses. Do you think this improved your ability to think critically about an issue?
6. Was attending the Graduate Student Showcase and subsequent lab meeting about projects helpful? Why (what did you learn)?
7. Please list and describe ten new things that you learned while taking this class.

Results

Course enrollment

During 2015 -2017, twenty-three students enrolled and finished the fall section of the course. One student was a Master's student, and the remaining were undergraduate students in their senior year. Student majors were in five different departments: Biomedical Sciences, Biology, Psychology, Neuroscience and Microbiology (Figure 1). Most students were from Biomedical Sciences. Fourteen females and nine males took the course during this time and three were minority students (Figure 1). Thus, during the three-year enrollment, the course profile was 61% female and 13% minority students. Based on freshman profile data from four years earlier (since most of the students were seniors), the proportion of females was slightly higher than the approximated overall population of the CSU senior class, and the proportion of minority students was slightly lower. Data used to make this comparison were taken from the CSU freshman profile website: (http://irpe-reports.colostate.edu/pdf/freshprof/Freshman_Profile_FA13.pdf), which indicated that freshman students enrolled during 2011-2013 included an average of 19.53% minority students (2011 -18.9%, 2012 – 19.2%, 2013 – 20.5%) and approximately 55% of the freshman class was female (2011 - 55.5%, 2012 – 55.5%, 2013- 54.6%).

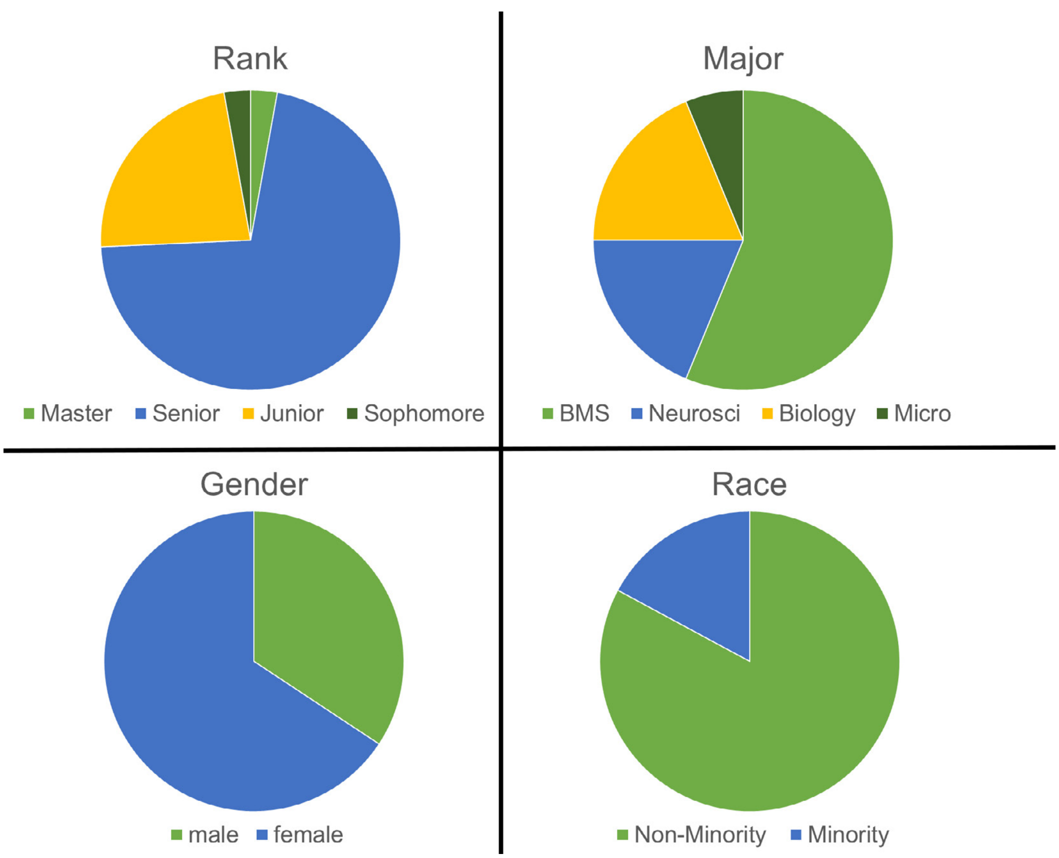

Figure 1. Pie Charts Illustrating Student Demographics. Over a three year period, 23 students finished the undergraduate research course. Information about class status, major, gender, and minority status was entered into an Excel spreadsheet and used to generate the charts.

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Overview of course

The goals of the course were outlined in the syllabus as follows:

After successful completion of the course, it is expected that students will be able to:

- Describe the training and safety measures that are needed for specific types of research.
- Formulate a testable hypothesis for a research-based question in neuroscience.
- Perform a small number of scientific techniques with confidence and expertise.
- Maintain an organized, complete laboratory notebook.
- Work independently on a research project in the laboratory.
- Discuss a research project with their peers and faculty members.
- Describe how a lab meeting is organized and undertaken.
- Describe how basic research is done in a university laboratory.

The first three learning objectives were initially addressed by incorporating short (15-20 minute) presentations by the instructor into the class time, by online training, and by hands-on training in the laboratory. Instructor presentations covered general information about research, maintaining laboratory notebooks, the focus of the project and underlying neurobiology principles, and the overall questions being investigated. Training included:

1. Completing the Responsible Conduct in Research (RCR) online course required by CSU for undergraduate students, graduate students and postdoctoral fellows: (https://vpr.colostate.edu/ricro/rcr/csus-rcr-training-policy-overview/)
2. Two online courses provided by the CITI program: Biomedical Research and Basic Course and Good Clinical Practice Course for Clinical Trials Involving Devices: (https://about.citiprogram.org/en/homepage/ https://about.citiprogram.org/en/series/human-subjects-research-hsr/)
3. CSU's Hazardous Waste training: (http://www.ehs.colostate.edu/WHazWaste/Home.aspx).

These online courses introduced students to key concepts in research, including ethics, conflict of interest, safe laboratory practices, data handling and ownership, how to interact with human participants properly, and how to handle waste correctly. In addition, following training, there was a discussion about the necessity of completing training prior to beginning a research project. This was done to emphasize that scientists are required to follow specific rules and student investigators are also charged with responsibilities while engaged in that research. Students spent time, both in and outside of the class, to complete the training courses and printed completion certificates were required by the second week of the course. These were stored in a three-ring notebook in the lab for the duration of the semester. During the first week, online training and initial presentations about the research topic were interspersed with sessions where students began learning how to use laboratory equipment. This involved demonstrations by the instructor and other project personnel. Student learning with respect to the first three learning objectives continued throughout the semester since the initial ideas and training were reinforced as the students conducted research and analyses.

Progress toward most course objectives was achieved by active participation in question-driven research, interactive learning via lab meetings with other students and the instructor, and by creating and giving formal presentations. Assessment consisted of weekly attendance, progress and participation, laboratory notebook checks, laboratory etiquette and safety, two oral presentations, and one final report. There were multiple opportunities to earn participation points during instructor presentations and during laboratory meetings when each group discussed recent experiments and results. Emphasis was placed on participation and experimental progress rather than on formal presentations or papers as indicated by the grading rubric (Figure 2).

Grading Scheme:

Quiz over syllabus	20 points
Participation in lab meetings	150 points
Lab notebook checks	200 points
Lab etiquette and safety	70 points
2 formal presentations	100 points
1 final paper	60 points
	600 total points

Grade Breakdown:

540 - 600 A
480 - 539 B
420 - 479 C
360 - 419 D

Figure 2. Grading Scheme for the 2017 Course. Students could potentially earn 600 points during the semester and these points reflected a quiz over the syllabus, participation, laboratory notebook work, lab etiquette and safety, two formal presentations and a written paper. Note that notebook checks and participation were weighted the most heavily.

Laboratory notebook checks were weighted the most heavily (a third of the grade) and students received substantial guidance and instruction throughout the semester on this topic. A brief presentation was given at the beginning of the semester covering good notebook practices and this

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presentation was posted on Canvas as a resource. Students were encouraged to ask questions as they documented methods and experiments during class time. There were regular notebook checks throughout the semester and the instructor carefully read through all entries in each student notebook. In addition, a grading sheet with specific comments for each daily entry and the rationale for any points deducted was created. This was followed by one-on-one meetings with individual students to discuss the grading sheet and notebook entries. These checks also helped determine individual student progress with respect to experiments completed, data collected, and analyses performed. Finally, the thorough notebook checks increased the possibility of using student-generated data for future papers and proposals.

Participation, laboratory etiquette and safety were also emphasized in the course. These helped achieve the learning goal of being able to describe how basic research is done in a university laboratory, since research requires active participation and training and safety are important. During class time, the instructor would periodically assess current student activities and record this information for later integration into the participation grade. Occasionally students would need to be reminded to be productive and only work on material related to the research course. The instructor and lab personnel would also assist students with issues if necessary, although care was taken to allow the students to work through problems themselves. Communication was monitored periodically to determine if groups were working well together, to identify group leaders, and determine if any students were relying on others too much. The instructor was available during each class period for questions, discussions and assistance with experiments. During laboratory meetings, student participation was encouraged and documented. The lab etiquette and safety grade was influenced by completing training on time, following directions, and communicating with laboratory partners and the instructor about any absences or other events that impacted research during class time.

The students did two formal presentations during the semester to increase presentation comfort and skills, and to enhance individual ability to communicate science to others. The first was a Powerpoint presentation done in a small group format (two to three students/group). The goal was to cover background information about the project and rationale for experiments in addition to covering information about materials and methods. Initial, preliminary results were also included. This presentation was done in front of the rest of the students and comments and questions were encouraged. Following the presentation, the instructor met with each student to discuss the Powerpoint content and organization and the actual presentation. Positive comments and suggestions for improvements were discussed. For the final presentation, each small group (two to three students) created a formal research poster; specific topics for each poster were different. Examples of research posters were provided for the students, and the instructor and lab personnel were available for questions as students worked on the poster and presentation. The poster was created as a collaborative effort within the small group, but each group member was required to present the poster individually to the instructor at the end of the semester. This helped assess individual work, helped decrease student nervousness, and allowed the instructor to be supportive and give feedback during presentations. Students were encouraged to present their posters at a regional neuroscience meeting that semester (Front Range Neuroscience Group meeting, Fort Collins, CO), or at the Celebrate Undergraduate Research and Creativity (CURC) Symposium at CSU the following semester. Typically, one to two groups would take this opportunity. To date 11 of the 23 students (48%) have presented posters outside of the course.

In 2017, an additional activity related to the presentations was added midway through the course; the students were required to attend the Graduate Student Showcase at CSU and judge a poster. It was expected that this process would encourage the students to think more deeply about poster organization and presentation prior to their own end-of-semester presentations. The assignment was possible because the showcase was on campus and occurred during class time. Each student was given a judging rubric and instructed to visit at least three posters and to focus on one of these for judging. In addition to the rubric, the assignment asked the students to consider specific questions and be ready for a discussion the following class period (Appendix 1).
Attendance was taken at the showcase and an extra assignment related to the activity was added to the grading rubric for the course (20 points for the activity, judging and subsequent discussion).

Students were required to write a research paper by the end of the semester. Instructions for the paper were posted on Canvas and conveyed verbally. A standard research paper format was expected that included an introduction, methods, results, figures, conclusion/discussion, acknowledgements and references. Students spent time, in and outside of class, working on the papers and figures. The instructor and lab personnel were available for questions, assistance and discussions. The papers were individual efforts although data and some analyses were shared by students. Each student was encouraged to focus on slightly different questions to address and to try do their own statistics and analyses. Peer assistance was not discouraged however, and in some cases, students with more statistics background would teach other students how to analyze data. The goals of the research paper included increasing student written communication skills, helping the students think about developing hypotheses, and providing an opportunity to re-examine methods, analyses and results that were done throughout the semester.

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Student reactions to course

In general, both verbal and written student comments were positive. All 23 students who completed the course filled out standard CSU course surveys and 16 students added written comments to the survey in the space provided. Mean scores on a five-point scale for all questions relating to the course and instructor ranged from 4.33 – 5 (above average to excellent), with the exception of responses to the intellectual challenge of the course. The mean rating for this question ranged from 4.0 – 4.33. Questions regarding the quality of the classroom and equipment scored lower, with mean scores of 3.67 – 4.25. A sample of the course survey questions and student responses is shown in Figure 3.

Many students wrote additional comments in the space provided on the standard survey. Written comments that were repeated by multiple students were the following:

1. Three students stated the course was one of the best or favorite courses they had taken at CSU.
2. Seven students wrote that it was great to get research experience and/or they learned a lot about research.
3. Three students pointed out it was a unique course or opportunity.
4. Two students stated that they liked getting to know peers and the instructor or liked working in groups.

Thirteen students filled out the custom survey, which was available to students at the end of the 2016 and 2017 fall semesters. Three questions on the two surveys were the same, but the instructor changed and added questions to the 2017 survey to better evaluate student perceptions. Seven students responded to the additional survey questions provided in 2017.

Student responses to the three questions asked in both 2016 and 2017 will be discussed first. In both years, students were asked to identify two unique features of the course relative to other courses. Responses included having the opportunity for interactive, hands-on learning, collaboration and applied problem solving, feeling responsible for the project and not just the grade, and independence. Students also mentioned the opportunity to work on real world issues, the ability to learn specific skills for research including the proper way to keep a laboratory notebook, and the opportunity to do long-term data collection and analysis. The opportunity to have one-on-one feedback from the instructor was also mentioned and that working with, and collecting data from real human participants was unique. The second question asked students whether they felt they had experienced "hands-on" research and if they were better able to consider academic research as a career. Twelve students answered this question and all replied

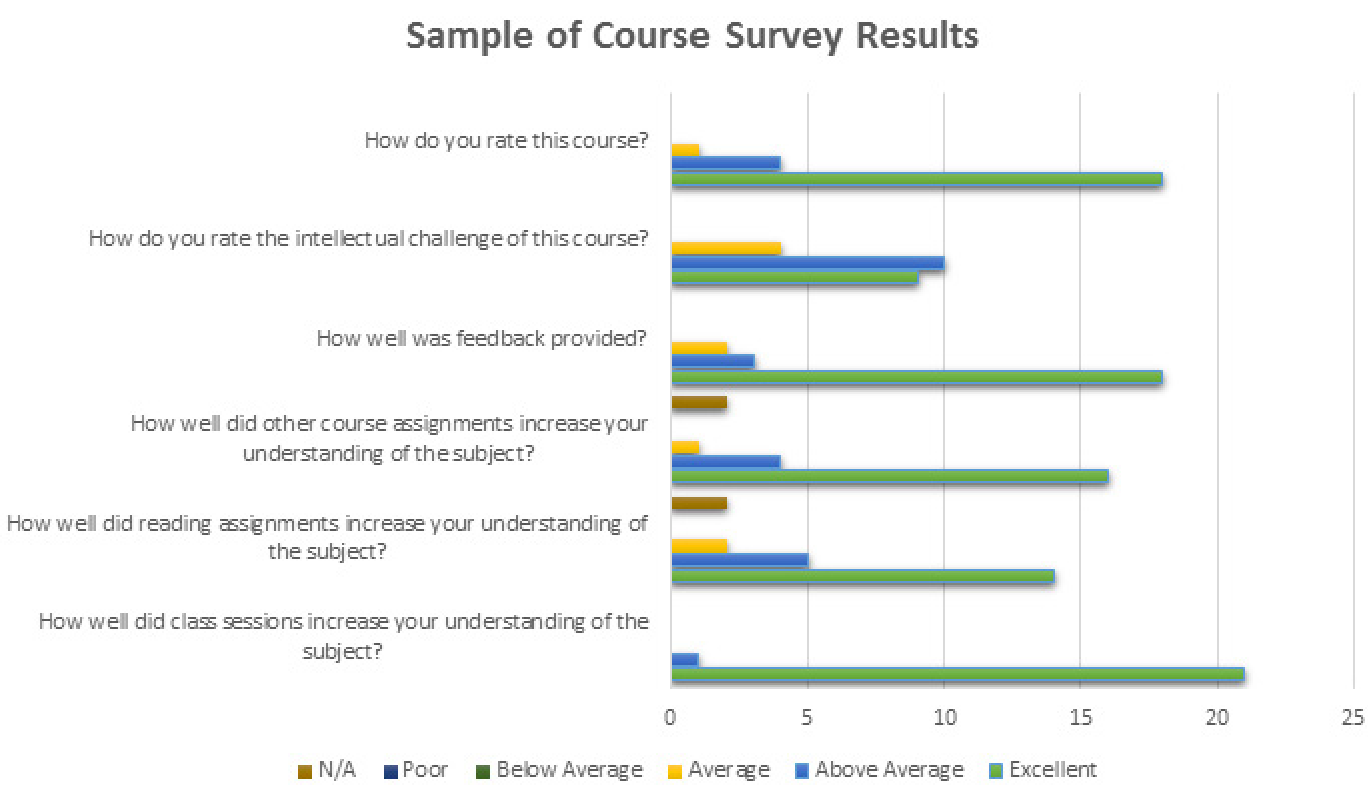

Figure 3. Sample of student responses to the standard CSU course survey. In general students rated the course as excellent or above average.

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yes. Additional student comments included that they had a better understanding of how to conduct academic research and that they learned specific research skills such as how to write a research paper. The third question asked if the student had suggestions for changes to the course. Students responded that they would have liked more time for experiments, to know the research topic when registering for the course, and to design their own projects. A few students mentioned that more funding and technology would be helpful, and one student commented that presenting the research poster at a meeting should be required.

In 2017, additional questions were added to the survey and seven students responded to these questions. The first question asked about the presentations, what was learned, and if the student felt more confident about their ability to talk about research projects following the presentations. Students responded that they learned more about the research topic and how to: communicate research clearly, explain their research to someone else, format a research poster, present analyses and methods, and present a poster for a regional meeting. Additionally, students reported that they learned more about the research topic and the depth at which research should be understood to present it to somebody else. Four students stated that the experience made them more confident with respect to future research presentations. One student stated that he/she already felt confident presenting research, and two students did not specifically address the question. The second new question asked in 2017 centered on the requirement that students needed to figure out solutions to technical issues and how to do data analysis with limited instructor assistance. They were asked whether they thought this approach improved their ability to think critically about an issue. All seven students answered "yes" or "definitely". Five students responded that this unique feature of the class gave students direct involvement with the research and required that students use problem solving skills for real issues and analyses, and that encountering roadblocks really made them think through things and come up with solutions. Three students stated that activities in the course helped them realize that there are many different ways to solve an issue or problem, and one student reported that the requirement to figure things out was one of their favorite parts of the class.

In 2017, the class attended the Graduate Student Showcase, judged a poster and discussed this experience the following class period. The third new question asked students if they thought attending the showcase and the subsequent discussion was helpful and if so, why. All students indicated that they thought the experience was helpful. Six students stated that they learned more about the research taking place at the university, or that they enjoyed seeing posters covering other research projects. One stated that seeing the symposium made them appreciate where they are and that they made connections for future opportunities. One student stated that it was nice hearing poster presentations from more experienced people to see how it should be done. Another student commented that they learned presenters should ask a listener about their background at the beginning of a presentation so they can tailor the presentation to the audience. Three students indicated that they learned what judges look for when assessing research poster, had a better idea about poster format or learned what is appealing when presenting a research poster. During the subsequent discussion in class, students also verbally expressed that they learned a lot about both research and poster presentations and enjoyed the experience. Attending the Graduate Student Showcase appeared to be positive experience and will be a standard part of the research course in the future.

Finally, students were asked to list and describe ten new things that they learned while taking the course. Answers included learning about the neurobiology and science related to the project (all seven students), learning how to properly keep a laboratory notebook (six of seven students), learning that training and/or reading previous studies is/are necessary prior to beginning a research project (five of seven students), and learning how to use specific equipment and computer programs (five of seven students). Students also stated that they learned how to solve problems with equipment, apply statistics to real data, and create and present a research poster. Individual students mentioned that they discovered that research is more hands-on than anticipated, writing research papers is hard, and that critical thinking is important when doing research. One student noted that he/she learned it is possible to start a company from a thesis project.

In summary, responses to standardized and custom surveys indicated that most students felt that they learned more about the science related to the project, what is involved in laboratory research, and specific skills related to research, equipment and presentations. The responses also suggested that students felt increased competence with respect to solving problems and that they felt better prepared to consider a career in academic research.

Discussion

The purpose of this article was to describe the design, funding, and preliminary student responses to a hands-on undergraduate research course developed at CSU. The course was developed to increase opportunities for undergraduate research experience. Currently, two faculty members teach the course. One section focuses on human sensory substitution research; this section is described in this paper. The other section focuses on *Drosophila* research. Together, both sections allow 20 students per year (ten for each section) to get hands-on research experience. The current cap of ten students is necessary because work with human participants requires direct supervision by the instructor during experiments. For projects not centered on human research, the number of students in the class could be increased. However, the large amount of time dedicated to reviewing and discussing individual student notebooks might also influence the number of students a faculty member is able to supervise in the course. Physical space may also be a consideration.

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Participation in university research has student value even for undergraduates who do not plan to go to graduate school or pursue a career in research. Learning in the course is primarily achieved through active hands-on experiences, problem solving, group work, and discussions with peers and the instructor. Research indicates that this type of active learning is especially beneficial for undergraduate students, promoting growth in cognitive processes, skill development, and clarification and preparation related to career or post-graduate activities (Seymour *et al.* 2004). Additionally, a more active, realistic, problem-solving approach to student learning helps increase understanding, and information retention and transfer (DeHaan 2005). Critical thinking by students was needed throughout this course, contributing to its overall learning value. In contrast to a standard lecture based format, students engaged in research work on open problems with no known, or single answer. This type of problem solving is crucial for undergraduates because it is more applicable to the real world and moves students away from thinking there is only one answer to specific problems that can be memorized and repeated (Hager 2003). Students also had to troubleshoot experiments and deal with technical issues, which required problem-solving skills. In addition, although some protocols were outlined for the students, others were not. For example, one set of experiments required that students read a paper describing a protocol (Nuessle *et al.* 2015) and use that information to design a similar, but slightly different approach for our experiments. This required downloading and installing Image J (NIH) on the computers, adding a specific plug-in (cell counter), uploading images they took in the lab, using Photoshop to apply a grid to the images, and using Image J to count structures in a specific and very detailed manner. These activities involved translating information in an article into physical steps that would result in an ability to carry out the task needed for the study contributing to development of critical thinking skills. Finally, studies also indicate that working in small groups and giving presentations contributes to critical thinking (Hager 2003) and these activities were integrated into the course design.

Communication skills were developed within the context of the course throughout the semester. Students worked in small groups, participated in laboratory meetings and learned to formally present their research and results in both oral and written formats. Individuals came into the course with varied backgrounds and students were encouraged to teach their lab mates if they possessed more knowledge or experience with a particular skill or content area. Improved oral communication skills through undergraduate research experiences has been documented previously (Seymour *et al.* 2004) and is an important skill in personal and work settings.
Based on responses to standard and custom surveys, students perceived the course as valuable and felt it contributed to overall growth in several areas, consistent with previous reports indicating the value of undergraduate research (Bauer and Bennett 2003, Merkel 2003, Seymour *et al.* 2004, Tan 2007). Specifically, students indicated that they learned how to prepare for, conduct, and communicate scientific research. In addition, they felt they learned more about the research topic and improved skills related to using research equipment, computer programs, working with others, and creating presentations. Students reported feeling engaged in critical thinking and problem solving throughout the semester and some reported discovering that there is more than one way to solve a problem. One interesting finding was that students rated the intellectual challenge of the course slightly lower than other than other aspects of the course (although it was still above average). Based on individual conversations and observations during the semester, it is likely that this is partly due to the lack of exams in the course and the opportunity to work independently and in small groups. The ability to get a lot of work done during the seven to eight hours of class time also likely contributed to this perception. To date, most students taking the course have had a strong interest in neuroscience and demonstrated enthusiasm for the research project and learning associated with the project. This may also have contributed to the perception that the intellectual challenge was not as stressful as in courses where exams are the primary means for assessing student learning. One caveat to keep in mind when discussing student responses in surveys is that course surveys can be unreliable in terms of gauging course and teacher effectiveness (Stark 2014, Uttl *et al.* 2017). A future goal related to this issue is to develop metrics that better evaluate student learning and engagement as well as intellectual and personal growth relative to the research class.

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This course would not have been possible without the vision and support of the Department of Biomedical Sciences at Colorado State University. In addition, Joel Moritz Jr., Marco Martinez, Tyler Allison and Josiah Racchini contributed time and expertise to the course and were critical to its success. We are grateful to our funding sources: The CSU Provost office provided funds to increase experiential learning, and the Departments of Biomedical Sciences and Mechanical Engineering provided additional support. The research was supported by the State of Colorado through an OEDIT Award (to LSR), and the City of Fort Collins and Sapien LLC provided matching funds for the OEDIT. Research was also supported by the College of Veterinary Medicine and Biomedical Sciences through a College Research Council Award to LSR and by a College Council Equipment Award to the instructors of both sections of the course. In addition, Drs. S. Tsunoda, C.W. Miller and C. Clay at CSU were instrumental for the creation and continued success of the course. Finally, we thank the undergraduate students who took the course, and our human participants for taking part in the studies.

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Literature cited

Bach-y-Rita P, and Kercel SW (2003) "Sensory substitution and the human-machine interface." *Trends Cogn Sci*. 7(12): 541-6.

Bauer KW and Bennett JS (2003) Alumni Perceptions Used to Assess Undergraduate Research Experience."*The Journal of Higher Education*. 74(2):210-230.

DeHaan RL (2005) The impending revolution in undergraduate science education. *Journal of Science Education and Technology*. 14(2):253-269.

Hager P, Sleet R, Logan P, Hooper M (2003) Teaching critical thinking in undergraduate science courses. *Science & Education*. 12:303-313.

Merkel C A (2003) Undergraduate research at the research universities. *New Directions for Teaching and Learning*. 93:39-53.

Moritz J Jr, Turk P, Williams JD and Stone-Roy LM (2017) Perceived Intensity and Discrimination Ability for Lingual Electrotactile Stimulation Depends on Location and Orientation of Electrodes. *Front Hum Neurosci*. 11:186.

Nuessle TM, Garneau NL, Sloan MM, and Santorico SA (2015) Denver Papillae Protocol for Objective Analysis of Fungiform Papillae. *J Vis Exp*(100):e52860.

Russell SH, Hancock MP and McCullough J (2007) The pipeline. Benefits of undergraduate research experiences. *Science*. 316(5824):548-9.

Seymour E, Hunter AB, Laursen SL, and Deantoni T (2004) Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education*. 88(4):493-534.

Stark PB (2014) An evaluation of course evaluations. *ScienceOpen*.

Tan EB (2007) Research experiences of undergraduate students at a comprehensive university. *International Journal of Teaching and Learning in Higher Education*. 19(3):205-215.

Uttl B, White CA, and Gonzalez DW (2017) Meta-analysis of faculty's teaching effectiveness: Student evaluation of teaching ratings and student learning are not related. *Studies in Educational Evaluation*. 54:22-42.

Appendix 1

Graduate Student Showcase Assignment Instructions:

Please be ready to discuss the following during the next class period:

1. The topic and overall focus of each of the three posters you visited.

2. In addition, for the poster you decided to concentrate on:

A. Have the presenter take you through the poster

B. Be able to give the class a summary of the goals for the project, the methods (brief – just an overview), main results, and conclusion for the poster.

C. Think about and answer the following questions:

- Was the poster well organized? Why or why not? Think about whether it flowed well, if you could read it easily, if the pictures were clear and well-labeled, etc.
- Did the presenter do a good job explaining why they were doing the work? In other words, what was the rationale for doing the experiments, or why was it important?
- Did the presenter do a good job describing the methods?
- Did they have a hypothesis that they were testing? What was it?
- Did the results clearly support their conclusions?
- Were they able to answer questions? Try to ask questions during, or after they take you through the poster.

(Note: the above bullet points are things that judges take into account when analyzing posters, so noticing these things will help with your own poster creations & presentations)

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Inexpensive Hands-On Activities to Reinforce Basic Physiological Principles: Details of a Soda Bottle Nephron Model

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Abstract
For many reasons, physiological aspects of anatomy and physiology laboratories are often presented as simulations. While simulations effectively convey concepts, hands-on activities promote more active student engagement. Recycled soda bottles, supplemented with other inexpensive readily available supplies, can be used to create working models illustrating concepts such as filtration at the glomerulus with reabsorption from the renal tubules, heart valve regulation of flow direction, negative pressure of inhalation, and fluid conduction of sound waves in the inner ear. These activities demonstrate basic biological properties, and allow for more in-depth student exploration resulting in enhanced cognition. The activities are well received by students who find them to be informative and fun. In this article, readers are guided through the construction of a model nephron with detailed step-by-step instructions and assessment tools. https://doi.org/10.21692/haps.2018.017

Key Words: nephron model, inexpensive laboratory, renal physiology, hands-on activity, simulation

Introduction
Life-long learning marks student success, which is the prime goal of teaching at all levels of education. Active engagement helps students develop critical thinking and problem solving skills essential in life-long learning. To promote these higher levels of learning, use of computer-assisted simulations and data analysis have become widely popular in medicine and life sciences (Lateef 2010, Hallow and Gebremichael 2017). Computer-assisted simulations and data acquisition systems, however, are often expensive and they leave physiological concepts in abstract form.

Simulations and model systems are most valuable when combined with actual experiments (Lewis 1989). This has been demonstrated at many levels of education. At the pre-college level, Yun *et al*. (2017) developed a model to examine hydrostatic filtration in the glomerulus. This was a well-received small group activity deemed successful due to its hands-on nature. Similar success has been observed at undergraduate institutions. For example, Krontiris-Litowitz (2003) demonstrated improved student grades with the use of manipulatives to demonstrate movement through membranes. Likewise, Rios and Bonfim (2013) found improved student engagement and enthusiasm when using model-building activities to explain sarcomere contraction. Carvalho and Giffen (2014) devised a laboratory activity focusing on renal cell models using small color-coded cardstock pieces that represented major molecular transporters and channels. The activity was well received and students reported enhanced understanding of renal physiology. At the graduate level, medical school students have exhibited a significant increase in test scores following hands-on modeling of obstructive and restrictive airways (Jamison and Stewart 2011), improved understanding of atherosclerosis using a mechanical device to alter blood vessel diameter (Almeida and Lima 2013), and improved performance following use of cost-effective hands-on simulations of neonatal intubation (Bruno and Glass 2016).

The hands-on soda bottle science models presented in this paper, and in the accompanying website-accessible documents, are easy to construct using inexpensive, readily available materials. Students work in small groups to apply their conceptual knowledge of renal, cardiovascular, respiratory, and auditory physiology from the laboratory to reinforce the concepts learned in the lecture setting. Four activities have been developed (Motz *et al*. 2016): the nephron model described in this paper, a heart valve model, a model of the lung, and a model of the ear. All of the models are available on the HAPS website at hapsweb.org **HERE**. Each activity description includes: an overview, learning objectives, materials, directions for assembly of the model, the procedure for the activity, and assessment questions.

Soda-bottle labs have been used by the authors as supplementary add-ons to standard laboratories, using models, dissections, wet-laboratory activities, or computer-assisted experimentations. These activities have been used over the past twenty years in anatomy and physiology laboratories first at a community college and, in the past ten years, at a four-year institution. The nephron and heart models have also been included for the last two years in medical physiology laboratories.

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The nephron model helps to facilitate true understanding of difficult physiological concepts such as glomerular filtration and renal reabsorption. Students are enthusiastically engaged during model construction and associated exercises. They remain engaged during critical analytical discussions of the results of the activity and the related physiological concepts they have learned. The dynamic, visual nature of the model enhances the static learning of renal physiology gained in lectures. Furthermore, students can manipulate the model to mimic abnormal functioning.

Materials and Methods

Soda Bottle Science: The Nephron.

The nephron model demonstrates glomerular filtration pressure, tubular reabsorption, and the relationship between blood, filtrate, renal extracellular fluid, and peritubular capillaries.

Time required

It takes approximately 15 minutes to set up this exercise and 5 minutes to run.
Once set up, the model can be easily modified to demonstrate changes in filtration membrane permeability and filtration pressure.

Learning Objectives

In conducting this laboratory activity, the student will:

1. Review major parts of a nephron. **HAPS outcomes module P 2.3a.**
2. Demonstrate the passage of materials through a filtration membrane. **HAPS outcomes module P 3.2 a, b, e.**
3. Understand the properties of the filtration membrane's effects on glomerular filtration. **HAPS outcomes module P 3.2e.**
4. Demonstrate reabsorption of materials from filtrate into the bloodstream. **HAPS outcomes module P 3.3d.**
5. Demonstrate the production of urine. **HAPS outcomes module P 3.1, 3.7.**

Overview

The nephron uses multiple processes to clean the blood. Blood is represented in this model by a yellow fluid (food color in vinegar solution) with small particles such as sand or glitter representing proteins, and larger particles such as red and white beads representing blood cells. Having different sized particles allows for demonstration of filtration by size (see Table 1).

Glomerular filtration uses blood hydrostatic pressure to push the blood through the filtration membrane. In the model, blood pressure is represented by gravity and a paper towel is used to represent the normal filtration membrane, which will filter by size. Replacing the filter paper with a fine mesh will allow passage of "proteins" whereas netting will pass "cells", demonstrating abnormal filtration. In contrast, a membrane less permeable than paper towels will result in decreased filtration volume, decreasing flow rate through the "nephron tubule" and decreasing production of urine over time.

The renal tubule adjusts the blood's water, salt, and glucose levels through the processes of reabsorption and secretion, resulting in a change both tubular and extracellular fluid volumes and concentrations. In this model, reabsorption is represented by diffusion through a permeable membrane "tubule". Fluid diffusing across the membrane has an accompanying colorimetric change (facilitated by a pH indicator dye) that represents the reabsorption of plasma constituents into the extra cellular fluid (ECF). Overflow of the fluid from the soda bottle kidney tissue into the collecting tray represents return of water and nutrients to the blood.

The fluid remaining in the renal tubule is eliminated as urine. This is demonstrated in this model by having a yellow colored fluid leave the renal tubule to drain into another container that represents the urinary bladder. Note that if the filter paper is replaced with more permeable netting, "proteins" or "cells" will be present in the final urine to demonstrate diseased states.

Table 1. Corresponding model and nephron components

Model Component	Nephron Component
Inverted 2-liter bottle top	Glomerular capsule
Paper towel	Filtration membrane
Vinegar	Blood plasma
Glitter	Large blood proteins
Solution in 2-liter bottle	Interstitial fluid (ECF) surrounding the renal tubule
3-liter bottle bottom or other	Peritubular capillaries
Small plastic container	Urinary bladder

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Assemble the model

Using Figure 1 as a guide, follow the step-by-step instructions below:

1. Cut the top off of a 2-liter soda bottle an inch below where the sides become parallel with each other. Note the black, broken-line marks on the 2-liter soda bottle (Figure 1A).
2. Take the cut-off top of the bottle and slip one end of a fabric tube over the mouth of the soda bottle and secure it in place with a twist tie. [We made several tubes out of scrap materials such as nylon and felt, as well as cotton socks, to give students varying permeabilities to experiment with.] (Figure 1B)
3. Cut a 1½" square in the side of the bottom part of the bottle which is 2 ½" from the bottom. Note the black broken line marks on the 2-liter soda bottle (Figure 1A).

For steps 4-11, refer to Figure 1C.

4. Pour water into the bottom of the 2-liter bottle up to, but not overflowing the hole.
5. Add two drops of a pH indicator into this water. Any standard pH indicator solution such as phenolphthalein or 1% Methyl red can be used. Alternatively, a red cabbage indicator solution can be made by boiling red cabbage in water for 1 hour and straining. The pH indicator should turn red when acidified.
6. Invert the top of the bottle with the nylon tube attached into the bottom of the bottle. The top of the bottle will represent Bowman's capsule, and the bottom of the bottle will contain the ECF that surrounds Bowman's capsule and the nephron loop.
7. Immerse several inches of nylon tubing into the water containing the pH indicator. Pull the end through the square hole that you cut.
8. Fold a piece of paper towel into a funnel so that it fits into the "Bowman's Capsule" (upside-down bottle top). This filter paper represents the filtration membrane.
9. Cut the bottom 2½" off of a plastic container large enough to hold the 2-liter bottle (a 3-liter bottle will work well, as does the top of a take-out container which is used in Figure 1). This larger container represents the peritubular capillaries.
10. Put the 2-liter bottle bottom containing indicator dye solution into the larger plastic container. When the model is active, fluid in the tubing (tubular urine) will be "absorbed" into the solution in the 2-liter bottle, thus increasing the ECF volume. Since water was filled to the level of the cut hole, a small amount of the fluid will spill over from the 2-liter bottle (representing the reabsorbed nutrients and water) into the larger container such as the take out lid used in Figure 1, which represents the peritubular capillaries.
11. Arrange the open end of the nylon tubing so it will drain into an additional plastic container which is cut to the same level and which represents the urinary bladder.

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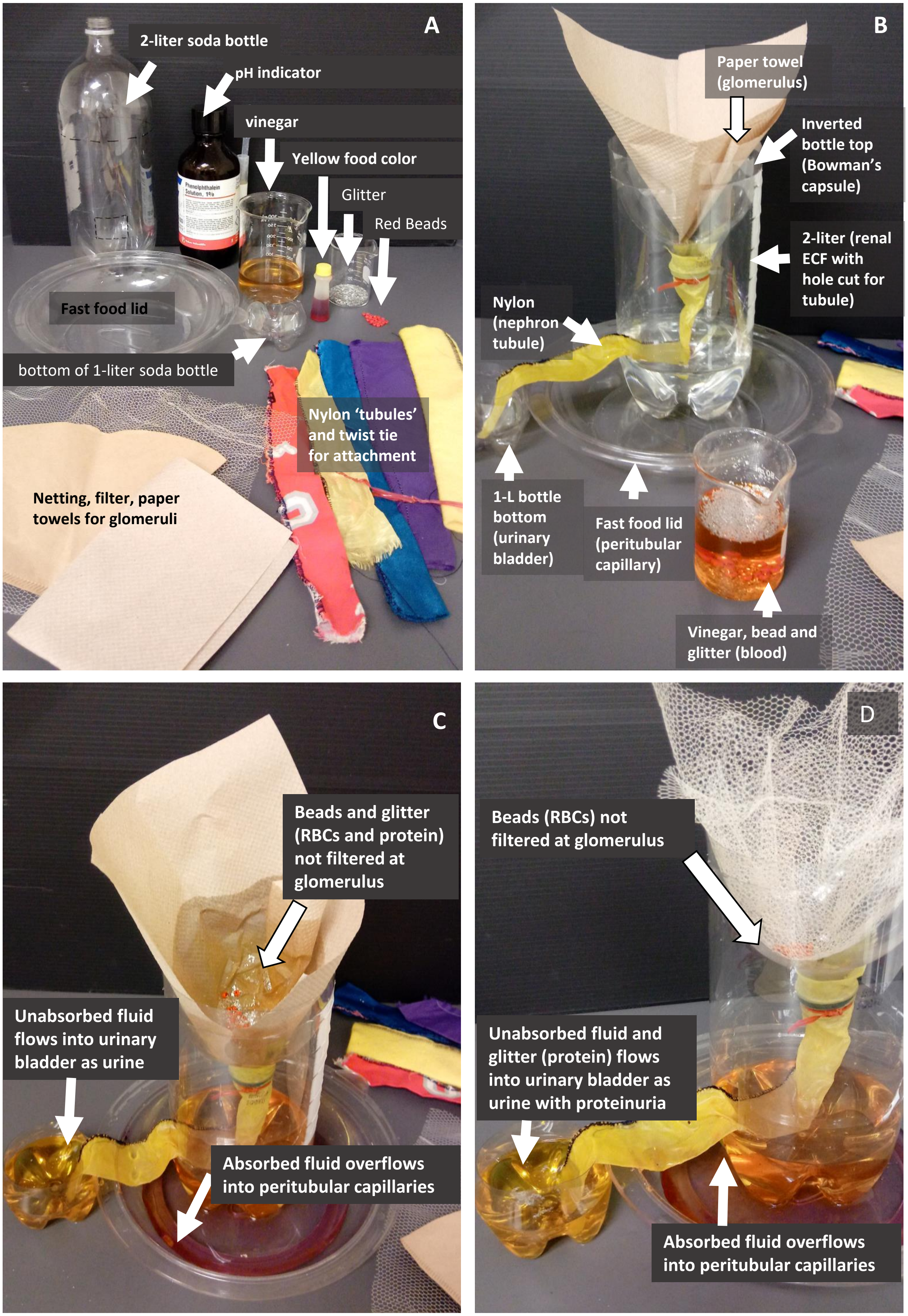

Figure 1. Guide for step-by-step instructions for nephron model

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Conduct the Activity

It is recommended that the instructor discuss which parts of the model represent which parts of the nephron prior to performing the activity. Alternatively, the instructor may want students to generate this information by exploring the materials.

1. Prepare the "blood": mix vinegar, yellow food coloring, red beads, and glitter.
2. Gently swirl, then pour the "blood" into the paper towel-lined "Bowman's capsule.
3. Record the time it takes for the blood to pass through the paper towel filtration membrane.
4. Make and record observations on what material stays in the paper towel, and what material goes through it.
5. Note the relative ease of flow of fluid through the wall of the tubing. The type of tubing chosen will have variable permeability. Thus, a tube made from a nylon stocking will be more permeable than one made out of felt, which will, in turn, have greater permeability than a tube made of rip-stop nylon. The tube can be made from any varied group of scrap fabrics to achieve this range of permeability
6. Observe and record any changes that occur as this fluid is "reabsorbed" from the "tubule" into the "ECF".
7. Observe the overflow of fluid from 2-liter bottle into the 3-liter container representing the peritubular capillaries.
8. Observe the flow of the fluid remaining in the nylon tubing into the container representing the urinary bladder.
9. Have students repeat the experiment using the model they have constructed and altering the procedure as follows:

   a) Alter the filtration membrane to demonstrate nephrotic and nephritic disorders by using more and less porous alternatives such as old stockings, cheesecloth, mesh or filter paper.

   b) Alter "reabsorption" by switching the "rip-stop" nylon with alternative materials to represent alterations of transmembrane transport.

   c) Alter the amount of vinegar mixture poured into the funnel to represent high blood pressure or decreased renal flow.

Assessment questions can be added to student laboratory report requirements to demonstrate understanding of material (see Table 2).

Table 2. Potential assessment activities/questions

If Table 1 is not provided to students, students could be asked to generate it.
What materials remained in the paper towel? Why? How does this relate to what happens during filtration?
What is the purpose of the pH indicator in the water? What does the change in the color of the water indicate has happened?
If students try alternate filtration membranes, they should compare the times required for passage through the membranes. The data should be accompanied by discussion.
In some kidney diseases, inflammation can block the filtration membrane, making it difficult for filtrate to form. How does this difference relate to the original paper towel and the filter paper?
Some kidney diseases cause the glomerular membrane to deteriorate. The resulting enlarged filtration slits allow larger proteins to enter the nephron. Since there are no recovery mechanisms in place for these proteins, they are lost in the urine. How does this relate to the use of cheesecloth versus the original paper towel in the results obtained? How would the rate of urine entering the bladder differ?
In a stress situation, the sympathetic nervous system would decrease the flow to the kidney. How does decreasing the amount of vinegar used affect renal function?

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Discussion and Conclusion

Anatomy and physiology laboratories at the authors' institution are conducted as a series of stations where students complete an activity at each station. This permits students to move at their own pace and is especially conducive to laboratories in which there are insufficient models/slides/computers to have one at each station. Each student group thus explores the soda bottle model independently of the rest of the class.

When this nephron model was used to supplement the didactic renal physiology, 100% of student investigators understood the representation of the filtration membrane and Bowman's capsule as well as implications of differential permeability of the membrane. However, fewer than 75% of students were able to make physiological connections for the overflow into the larger container and for the colorimetric change without explicit instructor explanation, as evidenced by poor answers on lab reports for this item.

In actively constructing the model, students reinforce their anatomical knowledge of the nephron, as they are directed to draw correlations between model components and nephron segments. Students responded favorably to making the model and especially enjoyed evaluating the model as to where it correctly or incorrectly demonstrated physiological actions of the nephron (i.e. showing reabsorption but not secretion; or failing to demonstrate differentiation between parts of the nephron tubule).

Students, on the whole, enjoyed the opportunity to take ownership of the experiment. The ability to investigate independently by choosing which materials to utilize in a modified nephron model stimulated student curiosity. Because of this, the Soda Bottle models have greater potential for encouraging life-long learning than if only more traditional, less hands-on, activities are used.

Continual modernization and update of laboratory equipment can pose an economic challenge, which can be mitigated with creative use of low cost materials. Soda-bottle models are a hands-on laboratory learning tools that are inexpensive to construct, yet they greatly enhance interactive and collaborative small-group learning, critical and analytical thinking, problem solving, and effective communication skills.

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Literature cited

Almeida JP, Lima J (2013) An education device for a hands-on activity to visualize the effect of atherosclerosis on blood flow. *Advances in Physiology Education.* 37(4):427-435. http://dx.doi.org10.1152/advan.00065.2012

Bruno, CJ and Glass KM (2016) Cost-effective and low-technology options for simulation and training in neonatology. *Seminars in Perinatology* 40 (7): 473.

Carvalho, H and Giffen ZC (2014) Hands-On Activity for Nephron Physiology Education: One Example of Active learning. *Research Gate Publications.* 13(4):52-56. doi: 10.12957/rhupe.2014.13954

Hallow, KM and GebremichaelY (2017) A quantitative Systems Physiology Model of Renal Function and Blood Pressure Regulation: ModelD. *CPT Pharmacometrics Syst Pharmacol* 6(6):383-392. doi: 10.1002/psp4.12178

Jamison,JP and Stewart MT (2015) Simulation using novel equipment designed to explain spirometric abnormalities in respiratory disease enhances learning in higher cognitive domains, *Advances in Health Sciences Education* 20 (4): 1011.

Krontiris-Litowitz J (2003) Using manipulatives to improve learning in the undergraduate neurophysiology curriculum. *Advances in Physiology Education* 27(1-4):109-119.DOI:10.1152/advan.00042.2002

Lateef, F (2010) Simulation-Based Learning: Just Like the Real Thing. *J Emerg Trauma Shock* 3(4): 348-352. doi: 10.4103/0974-2700.70743

Lewis, R (1989) Computer Simulation in Science: Pros and Cons. *The Scientist* November 27. 1989 Issue.

Motz VA, Suniga RG and Connour J (2016) Inexpensive Hands-On Activities to Reinforce Basic Physiological Principles. *HAPS 2016 Annual Meeting and Workshops*, Athens, Georgia.

Rios, VP and Bonfim VMG (2013) An inexpensive 2-D and 3-D model of the sarcomere as a teaching aid. *Advances in Physiology Education.* 37(4):343-346. https://doi.org/10.1152/advan.00111.2012

Yun, SM, Lee S, and Kim H-B (2017) Modeling Activity on Blood Filtration in the Nephron. *The American Biology Teacher.* 79 (9): 774- 77) DOI: 10.1525/abt.2017.79.9.774

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Jazz As a Model For Classroom Practice

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Abstract
A successful active learning community in which students engage in meaningful learning is characterized by a number of critical elements. These include a safe learning environment in which both instructor and students are willing to take intellectual risks and share their thoughts about content being discussed. Although many instructors recognize the importance of these elements, their classroom practice fails to implement the key factors that lead to success in the classroom. This article proposes the jazz experience as a model for developing a successful active learning community. While other models may certainly fulfill this role in various ways, jazz embodies all critical elements of such a community. https://doi.org/10.21692/haps.2018.014

Key words: active learning, classroom practice, helping the learner to learn, learning communities

Introduction
I am a physiology educator (Modell, 2004) whose mantra is "I don't teach, I help the learner to learn" (Michael and Modell, 2003). This mindset dictates what I do in the classroom. In order to help the learner to learn, I must foster an interactive classroom environment in which I can discover what kind of help the learner needs. Some time ago, I was watching a group of world-class jazz musicians perform, and I realized that what I do in the classroom is Jazz!

To appreciate the rationale behind this realization requires some historical perspective. Early in my career, I became convinced that better learning outcomes could be achieved if students were involved in learning experiences in which they are supplied with facts and guided towards reaching their own conclusions (i.e., an active learning environment) (Modell *et al.* 1974). Hence, my early educational efforts were directed toward providing medical students with resources and opportunities for engaging in active learning (e.g. Modell, *et al*. 1975, Modell 1986; Modell and Roman 1995)) and providing faculty with opportunities to learn about promoting active learning in the classroom (e.g. Modell and Michael 1993, Modell 1996).

In 1995, my view of the classroom changed dramatically. I finally accepted the fact that students are responsible for their learning (Rogers and Freiberg 1994). Providing resources and opportunities will not result in learning if students do not accept responsibility for that learning. If I could not impart knowledge to students (i.e. put knowledge in their brains), my role must be to help them engage in meaningful learning. Meaningful learning in physiology occurs when the learner builds mental models of physiological mechanisms that can be used to solve physiological problems (Michael 2001, Michael and Modell 2003). In order to help students engage in meaningful learning, I must have some idea of what kind of help they need. Hence, my role in the classroom changed from primarily being a purveyor of information to primarily being a "clinician" who diagnosed problems that his students were having in the learning process and helping them address those problems (Modell 2004).

Changing how I approached the Classroom
How did this change in mindset affect how I approached the classroom? The first change focused on setting educational goals for the day. With the older mindset, goals were focused on the type of information provided and the manner in which students would engage that information (Modell 1993). With the new mindset, additional goals were added that focused on the process that students followed to build their own mental models. These new goals require continual interaction among the students and between students and instructor. As a "clinician," the instructor must diagnose where in the process students are having difficulty and engage them in a dialog that will help them:

1) Recognize the limitations of their mental models (e.g. their misconceptions).
2) Recognize the limitations of the process by which they approach their mental model building (e.g. asking appropriate questions).
3) Revise their mental models and their model building process.

The second change deals with the nature of the interactive discussion that ensues as a result of the first change. The discussion includes opportunities for students to share their mental models and their mental model development process.

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An additional feature of this classroom environment is that the progression of the discussion is driven by the issues that the instructor (aka "clinician") diagnoses. Thus, unlike the older mindset, where the instructor plans the progression of the discussion from the "input state" to the "output goals" (Michael and Modell 2003), with the new mindset, the instructor must be prepared to vary the "path" of the day to fit the thought progression of the students. In other words, the instructor must be able to use the available resources in a variety of ways (determined by the perceived students' needs) to reach the output goals for the day. That is, the instructor improvises to address the needs of the learner. Hence, in this sense, what I do in the classroom shares the improvisation element of jazz. It is important to recognize that the instructor does the improvisation while helping the students recognize their current mental models, test their models, and refine their models (Modell 2004). The students are not expected to improvise, nor are they encouraged to improvise. They are encouraged to examine their current ideas (mental models), share those ideas with fellow learners, apply their models to problem solving (i.e., test their models), and refine their models to correct "errors" in their models.

If only the instructor engages in improvisation

If, in this model, only the instructor engages in improvisation, what is the rationale behind proposing jazz as a model for classroom practice? Recall that I was watching a group of world-class jazz musicians when I recognized that jazz provides a useful model for classroom practice. Jazz in performance, as I experienced when watching these artists, is all about engaging in a musical conversation among the artists. What I witnessed in that conversation went well beyond improvisation. A group of musicians were working in a collaborative manner providing support that encouraged members to take creative risks. It was clear to me that within this group, there was trust, good communication (albeit often non-verbal), encouragement, and a concern for the success of all group members.

Jazz in the education realm is an apprenticeship model. To provide students with the best opportunity to reach their potential as a jazz musician, jazz educators strive to build a community in which learners feel safe, supported, and are encouraged to take creative risks and share their ideas. Although these characteristics are the same for a successful learning community in any discipline, community building is seldom a primary goal in traditional classrooms. This experience set me on a quest to learn more about what motivates the world-class jazz artist; what features of the jazz art form can help inform my goals in the classroom, and how I can help other faculty incorporate these lessons into their classroom practice.

If the job is to help the learner to learn

Many instructors state that their job is to "help the learner to learn," but it is clear from observing their classrooms that they do not share the mindset that I adopted in 1995. Unlike the jazz musician, these instructors are not willing to take a creative risk that would allow them to improvise. "Helping the learner to learn" in their minds appears to reflect the "provider" role that I played prior to 1995.

Dee Daniels, a world recognized jazz vocalist, often tells her students of an experience she had early in her career (Dee Daniels, personal communication) that can serve as a metaphor for this role. She was about to perform at a major jazz festival and experienced "an overwhelming rush of adrenaline", which is not a good thing for a singer. Just prior to being called on stage, she was able to quiet down the adrenaline by deep breathing. At that point she had a momentary "vision" of herself being a conduit for loving energy via her music. Everyone in the performance space was on the receiving end of the conduit. Her interpretation of the event was that, because of her focused intention, everyone present would be empowered/inspired by the music in areas that they alone knew were areas in which they needed empowerment or inspiration. Her job was to focus her energy in the moment with the intention of making the music available on the highest level.

Everyone present in that moment could choose to take what he or she needed from the experience. In other words, she [jazz singer Dee Daniels] served as the conduit, but each listener was responsible for using the energy and inspiration of that moment for answering their own needs.

In an educational setting, the message is that the instructor provides an opportunity, but the student is responsible for his or her learning. The "helping the learner to learn" mindset recognizes that the student is responsible for his/her own learning, but the role of the instructor goes well beyond Daniels' vision. By embracing the "clinician" aspect of the mindset, the instructor must also engage the learners in a dialog that provides information about the learners' mental models and how they are applying those models to solve problems. It is only through this type of exchange that the instructor can assess the needs of the learner.

Engaging in the clinician aspect of the instructor's job

Many instructors envision their role in the classroom as helping the learner to learn. However, their classroom practice is reflective of Daniels' vision. They are willing to provide information, activities, and answers to questions, but they have not embraced the "clinician" aspect of the mindset when working with learners who are responsible for their learning. Reasons for this adherence to only the role of provider are varied and complex. Some instructors apparently do not

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feel as if they have enough experience with the content to identify "problem areas" that students may be having. They seem to be afraid of misleading students by giving "wrong answers." Others appear to believe the myth that they should be the "sage on the stage" rather than a facilitator of learning. Still others have not accepted the fact that the student is responsible for his or her learning. Disseminating information, an often-necessary element of helping the learner, is not the same as helping students learn how to use that information. Facilitating learning requires interaction among students and between the student and the facilitator. The question is " How can I help colleagues recognize these facts and adopt a mindset that will allow them to promote a learning environment consistent with the 'helping the learner to learn' mindset that I adopted in 1995?"

What are the rules of jazz?

To seek the answer, I began asking jazz artists that I know, "What are the rules of jazz that allow you to perform jazz?" I was not looking for the "musical rules of jazz" that govern chord progressions and rhythm changes. I was looking for the mindset changes that led them to jazz and the practice of improvisation. Since many of these artists are also jazz educators, I was also looking for insights about their interaction with students. The parallels that I discovered between their paths in music and my path as an educator were amazing and helped me realize that I do, indeed, follow the jazz tradition in the classroom. The goal of this communication is to share what I learned in this quest and what I learned about jazz that makes it an excellent model for classroom practice aimed at helping the learner to learn.

Making mistakes

The first challenge for instructors and students alike if they are to engage in a meaningful learning experience is to be willing to take an intellectual risk and make a "mistake" (i.e. test their mental model). Instructors and students often fear that making a mistake or giving the "wrong" answer to a question will result in a negative experience. In fact, meaningful learning only occurs when the tests of our mental models do not predict what we see in nature (i.e. we make "mistakes"). In jazz, musicians embrace the notion that making mistakes can lead to a positive experience. For example, one artist, while recounting an early experience in her career, gave herself permission to improvise when she asked herself prior to a performance, "What's the worst thing that can happen if I make a mistake?" Her answer was that she would learn something to help improve the next performance. A former student of Oscar Peterson, the legendary jazz pianist, told me that Peterson told his students that if you make a mistake and can repeat it, you have not made a mistake, you have made a new arrangement.

Making "mistakes" is critical to meaningful learning and conceptual change (Bransford *et al.* 2000, Michael and Modell 2003). We learn by building mental models, testing those models, and modifying them on the basis of the outcome of the test. The instructor should not be the "sage on the stage" who is not allowed to make mistakes. The instructor should model behavior that leads to meaningful learning, and that behavior includes testing their mental models in ways that often leads to making erroneous predictions (i.e. "mistakes"). By being comfortable in this role, the instructor gives students permission to make mistakes and guide them in revising their models. An artist summarized this process in musical terms by stating, "The essence of improv is finding freedom in form. A musician takes the form of melody, rhythm and harmony and plays with this form in a free, intuitive way, harmonizing, embellishing, commenting and expressing feeling and ideas in unique ways that feel expressive of the moment." (Ann Hampton Callaway, personal communication, June 2014) In other words, she manipulates her mental model (testing it) and revises it until it conveys the message that she wishes to convey. The artist is modeling the creative process (and the process of meaningful learning). Many classroom instructors fail to recognize that their primary role in classroom practice is also to model a process. In this case, the process is the manner in which he or she builds and applies his or her mental models to solve problems in her/his discipline.

Keeping the melody in mind

Another artist told me that a primary rule when improvising is to "keep the melody in mind." In the realm of my classroom, this translates to "keep the performance goal in mind." In my view, we help students learn content so that they can apply that content to solve problems. Hence, for any given lesson or unit or course, one establishes performance (outcome) goals for what the student should be able to do at the end of the session, unit, or course. When helping the learner to learn, it is incumbent on the instructor to interact with students to learn where the students' challenges or difficulties lie. By keeping the performance goal (aka the melody), or "destination" for the journey, in mind, the instructor is able to help lead learners along a path that is consistent with the learners' chosen logic path toward the performance goal. In this process, the instructor adapts to the needs of the learner rather than the learner "switching gears" to follow the thought process of the instructor. This process also requires that the community of learners share their thoughts so that the community can reach a consensus model of the mechanism(s) being studied. Of course, it is essential that the instructor provide a safe, supportive learning environment where the student will be willing to engage in these behaviors (Michael and Modell 2003). Fostering this type of supportive community is also characteristic of the jazz education.

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Being in the moment
A common statement that musicians make when mentoring students is that, during performance, the performer needs to be in the moment. That is, one must focus on what is happening in the environment. As one artist explained, "Improv is like a meditation because you have to be totally in the moment. It is a dance between effort and grace because some of it feels inspired. Connecting mind and heart has so many benefits for all people." (Ann Hampton Callaway, personal communication, June 2014).

Being in the moment is also necessary for the instructor whose intent is to help the learner to learn. Being "in the moment" is all about maintaining focus on the learner. The instructor must listen carefully to what the learner is saying, pay attention to the language that the student is using, and seek clarification if the student's intent is not absolutely clear. "This is what I heard you say... ," for it is the words that the student uses that provides the instructor with clues about errors or inconsistencies in the student's mental model. Becoming distracted by thinking of an answer before the question is complete or assuming the existence of an error (misconception) based on sloppy language can potentially lead to more confusion rather than clarity. The students must also be "in the moment." To be a full participant in the learning process, the student must be actively engaged. The students directly engaged in the discussion must focus on the dialog in which they are engaged and seek clarification when necessary. The learners who are listening to the discussion must also maintain focus so that they can compare their mental models with those of the discussants. Being "in the moment" in this way requires that open communication exists among the discussants (instructor and students). The challenge is to create a safe environment in which students will be willing to take the risk to be fully involved in the process (Michael and Modell 2003, Modell 1996).

Creating a safe environment
So, how does one create a safe environment for learners; instructor and students? Here, again, jazz education can serve as a model. Contrary to the message that some high school students in jazz band receive, jazz is not a competitive sport. The jazz tradition is one of collaboration and support where ideas are exchanged freely to promote creative moments. As noted earlier, jazz education is based on an apprenticeship model. Older, more experienced, (master) musicians mentor younger musicians (apprentices) and encourage them to explore their ideas. Close observation of good jazz musicians reveals continuous communication among the performers and between performers and listeners. Each supports the others and encourages them to take creative risks. The tradition embraces mutual respect, learning and mentoring so that all artists can grow to reach their true potential. The same characteristics apply to a learning community in any discipline in which all members of the community are supported and encouraged to take the intellectual risks required to test their mental models and engage in intellectual "argument."

Traditional classroom environments, be they primarily didactic or those that include active learning modalities, seldom promote the development of a learning community. One reason often voiced by faculty for not establishing a learning community is that if time is devoted to promote such an environment, there is not sufficient time remaining in the quarter/semester to cover the necessary content. Emphasis on content (playing the correct notes) rather than process (performing the music) results in less meaningful learning.

The learning community
What are the relative roles of instructor and students in a learning community? In a jazz performance environment, we generally think of two populations of participants, the performers and the audience. However, in most cases, there are at least three populations. The first population consists of more experienced musicians (the "masters"). The second population consists of those performers with less experience (the apprentices), and the third population is the listening audience. Each population plays a critical role in the process. The "masters" serve as mentors for the younger musicians, sharing their experience and perspectives. The apprentices practice their craft under the supervision of the "masters," expressing their own creative ideas and receiving feedback from the "masters". The audience serves as observers. The distinction between these populations is often fluid because the mentors often learn from interaction with their mentees, and the audience provides feedback to all of the performers. All of populations are actively engaged in the process. We also find three populations in a successful active learning community although their roles are different from those in the jazz performance environment. The instructor is the "master." Students engaging in the conversation are the primary learners, and students listening to the instructor-primary learner interaction are secondary learners.

The instructor as mentor
The instructor serves as the mentor by posing appropriate challenges for students to test their mental models and by facilitating the session. As a "clinician," the "master" guides the learning, models the model building and problem solving processes, and provides constructive feedback to the primary learners. By being engaged in the model testing and refining process, some students (the primary learners) are apprentices in the sense that they are sharing their model building and testing processes with the community. Students listening to the conversation (secondary learners) compare their mental models to those of the primary learners, seek clarification from the primary learners, and provide feedback or alternative ideas to the community. Although the instructor is responsible for directing the conversation, each member of the community is responsible for his or her own learning and all members of

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the community benefit from the experience. The "clinician" (instructor) learns about the challenges facing the learners and often revises his or her own mental models as a result of these new insights. The primary and secondary learners learn how to use their mental models to solve novel problems. They also learn how to ask appropriate questions and seek appropriate answers when faced with other life challenges.

The learning community also adds another dimension to the learning environment illustrated by the following story. I once asked a member of a well-known vocal jazz group celebrating its 25th anniversary of performing, how she could perform a song that was in the group's original repertoire with as much energy as she had the first time she performed it. Her response was that the energy she brings to a performance comes from the audience. The energy in the room, and the success of the session, are directly related to the contribution made by the audience (in the learning environment, the learners). From the instructor's viewpoint, each class session is a "new day," potentially filled with new challenges. Although the same content may be repeated from previous sessions (or previous iterations of the course), the reason for the repetition changes, resulting in a fresh experience. Furthermore, the extent to which learning occurs in such a setting depends on the students' investment in the process. Student investment in the process will only be achieved if the environment is safe, all-inclusive, and supportive, another feature of the jazz experience.

The connection between the instructor (the artist) and the student the (listener)

The connections made between artist and listener during a jazz performance or among community members in a jazz education environment can be profound. The same can be said for the instructor and students in a successful active learning community. As one artist explained, "Love of one's craft and just love in general, is key in wanting to relate to people and make differences." (Karrin Allyson, personal communication). The relationship between artist and listener during a jazz performance typically lasts for the duration of the performance. The relationships that can form during the educational experience can last much longer, and, in some cases may change lives. If the instructor embraces the helping the learner to learn philosophy, a true concern for the student's progress can develop and result in enduring life-long lessons for students (Modell 2012). This is also evident in the jazz world when artists talk about the impact that their mentors in jazz had on their lives.

Jazz as a model for instructors

I have proposed that jazz can serve as an excellent model for instructors who wish to create a collaborative learning community in the classroom. Although others may propose other art forms as a suitable model for classroom practice, jazz embraces all of the key elements necessary for creating a supportive learning environment emphasizing the development of all members of the community to their maximal potential. An added benefit in this setting is that, while the learning process may be hard work, the community involvement makes the experience fun!

The parallels that have become evident between jazz and good classroom practice are not surprising. To be successful at both requires the practitioner to be dedicated to the pursuit of his or her craft in ways that can profoundly impact others. In many cases, the true impact of their work is not evident to the artist or educator. Each strives to be the best that they can be and gain satisfaction in knowing that they have made a contribution. However, as Dee Daniels came to realize through her "vision," the true benefit of the contribution lies with the recipient. In the case of jazz, it lies with the impact of the power of music in the life of the recipient. In the case of education, it is the degree to which the instructors' efforts empower students to go forth and make their own contributions to the broader community. Each shares a gift that enriches lives, keeps on giving, and all that jazz.

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Harold Modell received his PhD in Physiology in 1971. In 1985-1986, he was instrumental in establishing the Teaching of Physiology Section of the American Physiological Society, and, in 1988, Modell was named the founding editor of Advances in Physiology Education. In 1989, he gave up bench science research in favor of educational research and development. Activities in this realm have included research, materials development, and faculty development. He continues these efforts as Director of the Physiology Educational Research Consortium, and, until his retirement in 2015, was a faculty member at Bastyr University in Kenmore, Washington.

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Literature cited

Bransford, JD, Brown A, and Cocking RR (Eds) (2000) How people Learn: Brain, mind, experience and school. (Expanded Edition) Washington DC: National Academy Press.

Michael, Joel (2001) The Claude Bernard Distinguished Lecture: In pursuit of meaningful learning. Adv. Physiol. Educ. 25:145-158.

Michael, Joel A and Harold I Modell (2003) Active Learning in Secondary and College Science Classrooms: A working model for helping the learner to learn. Mahwah, NJ: Routledge.

Modell, HI, LE Farhi, and AJ Olszowka (1974) Physiology teaching through computer simulations - problems and promise. The Physiology Teacher. 3:14-16.

Modell, HI, AJ Olszowka, RA Klocke, and LE Farhi. (1975) Normal and Abnormal Lung Function - A program for independent study. New York: The American Thoracic Society.

Modell, HI (1986) Simulations in Physiology - The Respiratory System. Seattle, WA: National Resource for Computers in Life Science Education.

Modell HI and JA Michael (Eds) (1993) Promoting Active Learning in the Life Science Classroom. Ann N.Y. Acad. Sci.:701.

Modell, HI (1993) Why am I teaching this course? Setting educational objectives for course activities. In Modell H.I. and J.A, Michael (Eds). Promoting Active Learning in the Life Science Classroom. Ann N.Y. Acad. Sci.:701, 27-35.

Modell, HI and RI Roman (1994) Simulations in Physiology - The Renal System. Seattle, WA: National Resource for Computers in Life Science Education.

Modell, HI (1996) Preparing students to participate in an active learning environment. Am. J. Physiol 270 (Adv. Physiol. Educ.15):S69-S77.

Modell, HI (2004) Evolution of an educator: Lessons learned and challenges ahead. Adv. Physiol. Educ. 28:88-94.

Modell, HI (2012) Why do I do this? in (Rangachari and Dorsey Eds.) Students Matter: University teaching is rewarding. Southern Illinois University Press, pp. 135-151.

Rogers, C and HJ Freiberg (1994) Freedom to Learn (3/e) New York: Macmillan College Publishing.

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Saving Christmas: Use of Analogy to Teach The Compensatory Mechanisms of the Heart in Heart Failure

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Abstract
Students of physiology are taught that the body's homeostatic mechanisms are in place to maintain the body's internal environment. This is most often associated with maintaining health. Congestive Heart Failure represents a disease in which the body's homeostatic mechanisms worsen the progression of the disease. Using the analogy of Santa Claus delivering presents around the world in a single evening, students can gain a better understanding of how the body's attempt to respond to a deviation from homeostasis, the decrease in cardiac output, may drive the progression of the disease.
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Key words: cardiac output, stroke volume, heart failure, RAAS

Introduction
Students of physiology and biology are taught the concept of homeostasis. The term was coined by Walter Cannon in 1932 in *The Wisdom of the Body* and used to describe the internal constancy of the body. Decades earlier, the French physiologist Claude Bernard observed that the body's internal environment, or "*milieu interieur*", tended to remain relatively stable despite constant changes in the external environment (Fox 2016). Of course, a deeper understanding of homeostasis, such as the "set points" for various physiological measurements, developed over time. In most cases of injury, illness or disease development, homeostatic mechanisms prevent the onset of symptoms, or in serious cases, loss of life. Thus, when students are faced with a physiological scenario in which the body's homeostatic mechanisms actually exacerbate the very condition they were attempting to correct, confusion is reasonable and expected. In a2010 review article "Congestive Heart Failure: Where Homeostasis Begets Dyshomeostasis", the authors discuss the evolution of the understanding of homeostasis, and how homeostatic mechanisms can further contribute to the progression of a disease (Kamalov *et al*. 2010). The term, dyshomeostasis, was suggested by Richards to describe homeostatic mechanisms that were either inappropriate for the condition, excessive, or deficient to correct a dysfunction (Richards 1960).

The Dyshomeostasis of Heart Failure
Heart failure is defined as the inability of the heart to adequately meet the oxygen demands of the body on a persistent basis. In response to heart failure, homeostatic compensatory mechanisms take place that in the long-term cause further damage to the heart and worsen the progression of the condition (Porth and Gaspard 2015). These mechanisms include activation of the sympathetic nervous system, ventricular hypertrophy with chronic remodeling, and increased preload through activation of the renin-angiotensin-aldosterone system (RAAS) and the Frank-Starling mechanism (Porth and Gaspard 2015).

In the United States, heart failure is the leading cause of hospitalization among the elderly and affects over 5 million Americans, with 500,000 new cases diagnosed annually (Kamalov 2010). The worldwide prevalence for all types of heart failure in 2017 was 11.8% (Riet *et al*. 2017). Consequently, students taking physiology and pathophysiology will focus a great deal of time on the cardiovascular system and its common diseases. Students pursuing healthcare careers in particular will at some point inevitably encounter a patient diagnosed with heart failure.

Heart failure is a complex clinical syndrome that involves homeostatic responses from several other body systems. It presents a great opportunity for students to study homeostasis and integrate the function of several systems at once. In an undergraduate physiology or pathophysiology course, in which heart failure is a major topic, students must first recall and understand how cardiac output is determined. Then, they must understand the homeostatic responses to diminished cardiac output.

However, the responses to diminished cardiac output are the same homeostatic mechanisms that drive the progression of heart failure. In fact, today's standard of care for heart failure is focused on delaying disease progression, primarily by attempting to contain the body's homeostatic mechanisms

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(Kamalov *et al*. 2010). When the full mastery of a concept requires memorization, understanding and the ability to apply and analyze material, analogies may be a particularly helpful place to begin. Therefore, an analogy to a scenario where a mechanism should improve a condition in the short-term, but causes further problems in the long-term, is warranted.

In the activity that follows, students in an undergraduate pathophysiology course at Drexel University were presented with a simple analogy that should be easily understood. Moreover, it would be easy for them to explain to patients or others attempting to understand the condition. All images in the activity were hand drawn by the professor. Students in this course utilize Porth's Essentials of Pathophysiology as their primary text.

Student Activity

We have learned that heart failure is the inability of the heart to maintain sufficient cardiac output in order to meet the metabolic demands of tissues and organs. In other words, the body's tissues are not receiving the oxygen and nutrients they need to carry out normal function.

The most common cause of heart failure is atherosclerosis, which impedes blood flow through the coronary arteries supplying the heart. Other common causes are chronic hypertension, which makes it harder for the heart to pump blood through the arterial system, and valvular heart disease.

The human body is efficient at maintaining homeostasis. Nothing is more important to the body than meeting its oxygen demands and there are a number of homeostatic mechanisms in place to ensure that this is possible. These compensatory mechanisms of the heart/body are very helpful in restoring normal cardiac output.

To review:
<u>Increased preload</u>: According to the Frank-Starling mechanism of the heart, increased vascular volume (via activation of the RAAS system) will increase myocardial force of contraction, and therefore, the amount of blood ejected per beat.
Result: Increased myocardial contractility and stroke volume

<u>Myocardial hypertrophy</u>**:** Like any muscle of the body put under extra stress, the myocardium will grow larger, in an effort to get "stronger".
Result: Increased myocardial contractility and stroke volume

<u>Sympathetic Nervous System activation</u>**:** The sympathetic nervous system innervates the SA and AV nodes, as well as the myocardium. When cardiac output drops, SNS activation will occur. This will increase the rate and force of contraction.
Result: Increased heart rate, myocardial contractility and stroke volume

All of this sounds great, right? However, over the long term, adjustments are detrimental to the heart. Why?

To answer that question, let us recall what caused the heart failure in the first place. Since the most common cause of heart failure is atherosclerosis, we will start there. Atherosclerosis causes decreased perfusion of the myocardium, meaning the heart muscle itself is not getting the oxygen it needs to work effectively. People with heart failure due to atherosclerosis have often had myocardial ischemia, meaning that part of the heart muscle is incompetent (angina) or no longer functioning (infarction). Each of the three compensatory mechanisms listed here increases the heart's need for oxygen and nutrients, which it could not get enough of in the first place. Current management of heart failure is directed towards reducing the harmful consequences of these compensatory responses.

Now, what does all of this have to do with Saving Christmas? Analogies to things we all understand and can easily imagine can be powerful learning tools. In this exercise, we will use the example of Santa Claus attempting to deliver presents to all the children around the world in one evening to better understand heart failure. As you might have guessed, in this analogy:

Cardiac Output = All the children getting their gifts on Christmas morning.

Recall that Cardiac Output is defined as: Heart Rate x Stroke Volume. Let us establish what would be the analogous components in our Christmas story.

Presents to the children are the blood, filled with oxygen (Stroke Volume)

Santa and his sleigh (The heart)

The speed of the reindeer pulling the sleigh (Heart rate)

Imagine that one Christmas, Santa fails to get all the children around the world the gifts on their wish lists (decreased cardiac output). Santa is not being very forthcoming with Mrs. Claus about what is going wrong. Mrs. Claus, who has to receive all the sad letters the next year, decides to add some reindeer to Santa's sleigh to speed him up. Instead of four reindeer, Santa now has five:

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Figure 1. Santa has to carry extra reindeer food.

While this speeds up the sleigh at first, Santa still comes up short, because now he has to carry extra reindeer food. Carrying extra food causes the reindeer to get tired more quickly. So, the compensatory mechanism to speed up the sleigh (SNS activation to increase heart rate!) ultimately does more harm than good.

Mrs. Claus then decides that perhaps Santa simply needs to carry more presents. Perhaps the problem is that he is not leaving the North Pole with the number of presents he needs. In this scenario, children who wrote to Santa are like the cells of the body not receiving adequate oxygen, or the kidneys not receiving adequate perfusion.

Figure 2. Santa has to carry more presents

However, just like the added reindeer food, these added presents weigh down the sleigh, and the reindeer get too tired. So, the compensatory mechanism to carry more presents (increase stroke volume) ultimately does more harm than good.

Finally, Mrs. Claus decides Santa's sleigh needs to be expanded. Now he can carry enough food for the reindeer, and all of the presents.

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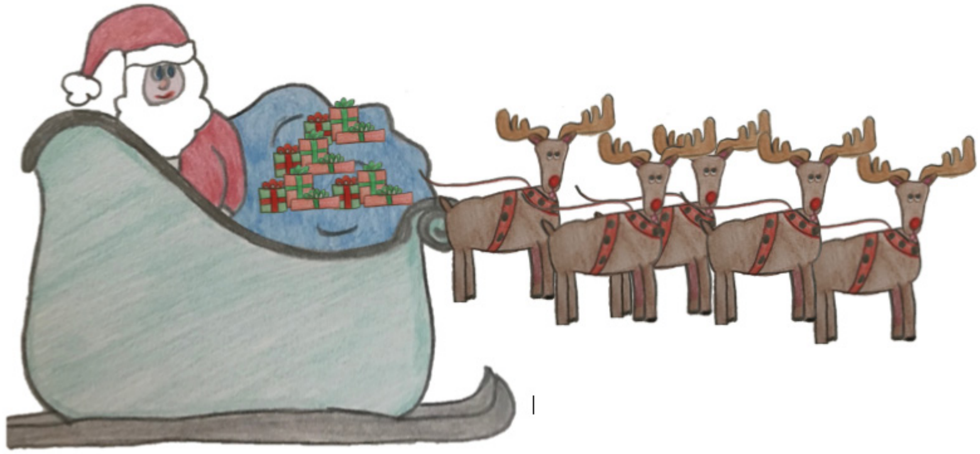

Figure 3. Santa needs a bigger sleigh.

Alas, Santa still fails to make his deliveries. Why? The bigger sleigh requires more gas, and that gas is Christmas spirit. What Santa and Mrs. Claus did not realize all along was that the lack of Christmas spirit was the problem in the first place, and nothing can replace it.

Imagine that Christmas spirit is the blood supply to the myocardium; it does not matter how the heart remodels if it cannot get the nutrients and oxygen it needs to meet the body's demands. Thus, the most common cause of heart failure, atherosclerosis, will always be the source of the problem.

What about chronic hypertension, another common cause of heart failure? Imagine hypertension like a strong wind blowing against the sleigh. It does not matter how much more powerful the sleigh is, or how much faster the reindeer are, or how many more presents Santa carries, if the wind that resists the sleigh does not stop blowing.

In your group, try to expand upon this story. For example, heart failure can be classified as systolic or diastolic dysfunction. What would be "wrong" with Santa's sleigh in these scenarios, and how would that impact cardiac output?

Review the common medications or other treatments for heart failure that we discussed in class such as beta blockers and diuretics. Do these measures target the compensatory mechanisms that Mrs. Claus tried, or do they actually assist the heart in maintaining cardiac output? What would be the consequences of surgical removal of excessive myocardial tissue?

Discussion

The story of saving Christmas is not for everyone. Any analogy in which the attempts to solve a problem (i.e. the homeostatic compensatory mechanisms) further exacerbate the condition would be appropriate. Challenge your students to create their own story. Whether as a formal assessment (perhaps a small group presentation) or just an activity to break up the normal class period, activities such as this can engage students in a creative process.

Furthermore, since this activity requires students to *remember* normal cardiovascular dynamics, *understand* how the heart responds to diminished cardiac output, and *apply* the compensatory mechanisms, it naturally takes students through Bloom's taxonomy of learning. If students then expand upon the story, or create their own, they are taking Bloom's taxonomy a few steps further to *evaluation* and *synthesis* (Krathwohl 2010). Students may appreciate the effort to bring humor into learning, and view the instructor as more approachable and invested in their learning. These factors have been shown to increase student self-confidence (Micari and Pilar 2012).

A note of caution is warranted in the use of analogies for complex physiological or pathological mechanisms. Brown and Salter (2010) recommend that analogies should be clear and well-understood by a student. Otherwise, explanation of the analogy can potentially lead to more confusion. They further suggest that analogies should also acknowledge the differences between the learned concept and the analogy and the limitations of the analogy's applications (Brown and Salter 2010).

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In conclusion, a simple analogy may improve student understanding of dyshomeostasis, as in the case of studying heart failure. Instructors are encouraged to challenge students to create their own analogies whenever a concept is particularly difficult to understand.

About the Author

Krista L Rompolski received a BS in Exercise Science and an MS in Exercise Physiology from Bloomsburg University, and PhD in Exercise Physiology from the University of Pittsburgh. She is a Certified Exercise Physiologist through the American College of Sports Medicine. Dr. Rompolski is the co-author and lead Digital Author of the 15th edition of Human Physiology, by Dr. Stuart Fox. She is an active member of the Human Anatomy and Physiology Society and the American Academy of Anatomists. Her teaching interests include pathophysiology, gross anatomy, and anatomy and physiology.

Literature cited

Brown S and Salter S (2010) Analogies in Science and Science Teaching. *Advances in Physiological Education* 34:167-169.

Fox S (2016) Human Physiology. 14/e. New York: McGraw-Hill.

Kamalov G, Bhattacharya SK and Weber KT (2010) Congestive Heart Failure: Where Homeostasis Begets Dyshomeostasis. *Journal of Cardiovascular Pharmacology*. 56(3): 320–328.

Krathwohl D (2010) A revision of Bloom's Taxonomy: An Overview. *Theory Into Practice*. 41(4): 212-218.

Micari M and Pilar P (2012) Connecting to the Professor: Impact of the Student–Faculty Relationship in a Highly Challenging Course. *College Teaching*. 60(2): 41-47.

Porth C and Gaspard KJ (2015) Essentials of pathophysiology: concepts of altered health states. 4/e. Philadelphia: Wolters Kluwer.

Richards DW (1960) Homeostasis: Its dislocations and perturbations. *Persepctives in Biology and Medicine*. 3: 238-251.

Riet E, Hoes A, Wagenaar K, Limburg A, Landman M, Rutten F (2016) Epidemiology of Heart Failure: The Prevalence of Heart Failure and Ventricular Dysfunction in Older Adults Over time. A Systematic Review. *European Journal of Heart Failure*. 18(3): 242-252.

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Teaching Acid-Base Homeostasis Using Collaborative, Problem-based Learning and Human Patient Simulators in a Physiology Laboratory

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Abstract
Students find it hard to understand acid-base homeostasis and the mechanisms involved in compensating for acid-base imbalances, including the role of the lungs and kidneys in this process. We have developed a laboratory activity based on collaborative problem-based learning and human patient simulators (HPSs) to teach this topic. Students (n=50) were divided into small groups and presented with five cases of acid-base imbalances simulated in HPSs. After recording various parameters including arterial blood gases, they collaborated in identifying the specific acid-base imbalance. An anonymous survey following the laboratory activity revealed that this laboratory improved their understanding of acid-base regulation (92%), improved quantitative understanding of acid-base physiology (90%), and improved understanding of acid-base imbalances (94%). https://doi.org/10.21692/haps.2018.013

Key words: acid-base homeostasis, pH imbalances, collaborative active learning, human patient simulators

Introduction
Educators employ various instructional methods to enhance student comprehension of difficult concepts and to help students develop independent problem-solving skills in particular areas. Since no one method is effective for teaching everything (Myers and Dyer 2006) there is a constant search for the best teaching methods to help instructors achieve their goals. Active learning is a method that has been found to be useful for teaching difficult concepts. Research suggests that active learning helps students develop the ability to think logically and to reflect upon known information (Paul and Elder 2001). Specifically, problem-based active learning engages students in finding solutions to real life situations, instills curiosity, and helps to transform students into lifelong learners. In this lab, the active learning component consisted of five human patient simulators (HSPs) that were used to simulate five acid-base disorders.

Collaborative learning is a teaching method that helps make learning enjoyable. It is a natural social act in which the students talk among themselves (Gerlach 1994). In collaborative learning, students have the opportunity to converse with peers, present and defend their ideas, exchange diverse beliefs, question other conceptual frameworks, and be actively engaged in the learning process (Smith and MacGregor 1992).

We used a combination of problem-based active learning and collaborative learning to teach acid-base homeostasis and simple acid-base imbalances. We believe that when both of these methods are combined they make it easier for students to understand the material, reflect upon what they have learned and retain their knowledge. We incorporated these methods of instruction into a laboratory activity in a physiology laboratory course (BIOL369). This laboratory is offered concurrently with the physiology lecture (BIOL368) course at Gannon University, Erie, PA. USA.

Materials and Methods
Five HPSs (Patient # 1- 5) were used to simulate five pH imbalances:

1. Partially compensated metabolic acidosis with high anion-gap.
2. Uncompensated acute respiratory acidosis.
3. Partially compensated metabolic alkalosis.
4. Compensated metabolic acidosis with normal anion-gap.
5. Uncompensated acute respiratory alkalosis.

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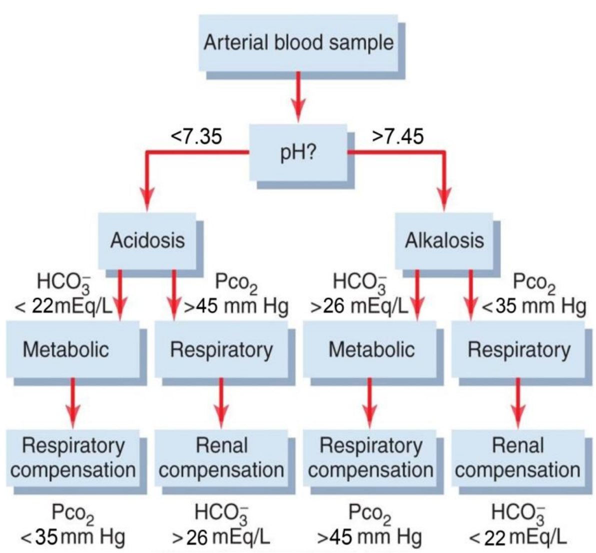
After a brief lecture on acid-base homeostasis and associated disorders at the beginning of the lab, students formed into small groups (three students/group) to work at the HPS stations. They recorded arterial blood gas (ABG) values, electrolyte levels (Na^+, K^+, Cl^-, $HCO3^-$), and other parameters from each of the stations in their laboratory report (Table 1).

Staying in the same group, students discussed and reasoned with each other to identify the imbalance and they completed the rest of the Table 1 calculations. Students used Figure 1 to identify the type of acid-base imbalance simulated and the level of compensation designated as complete, partial or no compensation. Figure 1 was adapted from the Guyton and Hall Medical Physiology textbook and is slightly modified for ease in making the required calculations.

Table 1. Identify the acid-base imbalances and the type of compensation simulated in patient simulators #1-5

Physiological Parameters	**Patient # 1**	**Patient # 2**	**Patient # 3**	**Patient # 4**	**Patient # 5**
pH	7.27	7.08	7.5	7.35	7.52
PCO_2	23	80	49	26	26
HCO3-	10	22	37	14	22
Na+	133	140	142	135	140
K+	6	4	5	3.3	5
Cl-	93	100	101	111	105
$\%O_2$ Saturation	91	89	93	95	92
Breathing Rate	12	5	12	14	17
Heart Rate	78	85	82	75	102
Blood Pressure	110/78	140/85	100/70	150/95	130/84
Expected pH					
Expected HCO3- in respiratory imbalances					
Expected CO2 in metabolic abnormalities					
(for metabolic acidosis only) Is this normal or high anion-gap and how much is the gap?					
(for respiratory imbalances only) Is it acute or chronic?					
Identify the degree of compensation and the systems compensating	Partial Compensation Respiratory	Not compensated	Partial compensation Respiratory	Complete Compensation Respiratory	Not compensated
Diagnosis	**Metabolic acidosis**	**Respiratory acidosis/acute**	**Metabolic alkalosis**	**Metabolic acidosis**	**Respiratory alkalosis**

*Figure 1. Flowchart for the analysis of simple acid-base imbalance**



**The flowchart in Figure 1 is adopted from Guyton and Hall's textbook of Medical Physiology (11th edition, 2006) and slightly modified for ease in the analysis of simple acid-base disorders.*

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After all of the students had finished their work, instructors disclosed the answers and verified their calculations. After the lab was completed, students' anonymous responses on the usefulness of a problem-based learning method in the understanding of acid-base homeostasis and imbalances were collected. Informed consent was obtained form those who participated in this study. Since the survey was anonymous and did not contain any personal information, the Institutional Review Board of Gannon University did not require an IRB application for this study.

Results

Student responses to the five questions in the questionnaire are shown in five pie diagrams (Figures 2-6). Analysis of student feedback revealed that the majority of students liked working with their peers and expressed high satisfaction in this learning activity.

Figure 2. Does this lab improve your understanding of acid-base regulation?

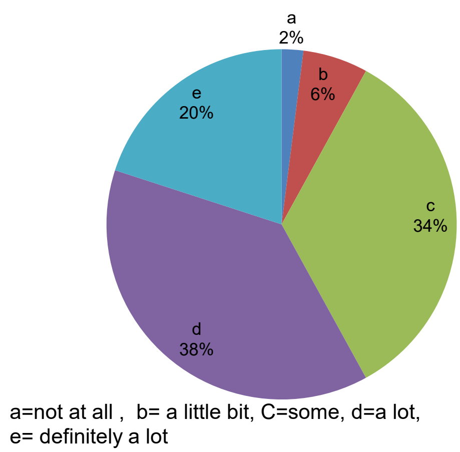

Figure 3. Does this lab improve your understanding of the role of pulmonary and renal systems in acid base regulation?

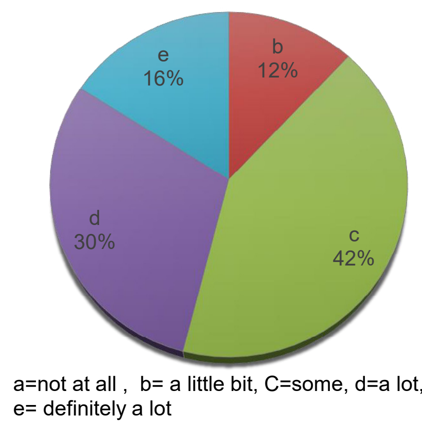

Figure 4. Does the calculating activities in this lab improve your quantitative understanding of acid base physiology?

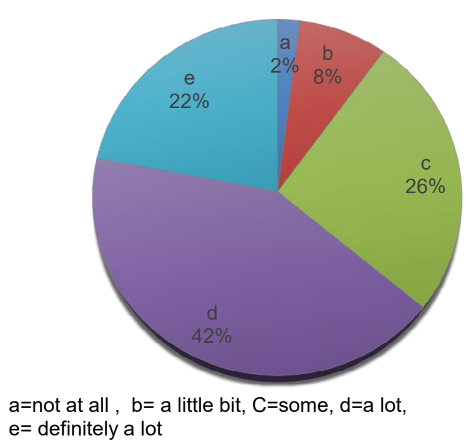

Figure 5. Students' feedback on their preference of acid-base lab with simulators to urine-based renal lab.

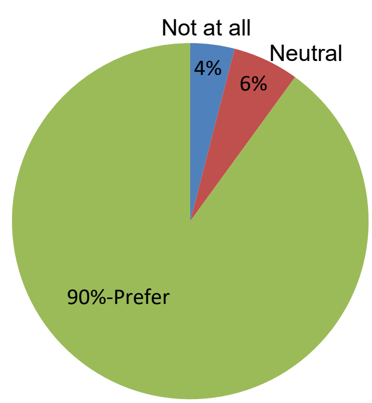

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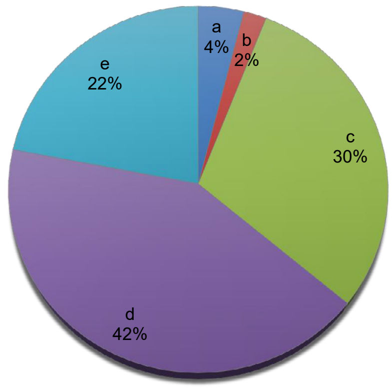
Figure 6. Does this lab improve your understanding of various acid base imbalances?



a=not at all , b= a little bit, C=some, d=a lot, e= definitely a lot

Conclusion

Fluctuations in the concentrations of H^+, HCO_3^- ions, partial pressure of carbon dioxide (P_{CO2}) and the subsequent changes in pH, along with compensation by the renal and respiratory systems to minimize these changes, can be difficult concepts for students to understand. In this laboratory, we attempted to teach acid-base homeostasis through the use of simulated pH imbalances. We simulated five pH imbalances in HPSs. Students were able to retrieve their previous knowledge of normal ABG values and compare them with simulated values in order to solve a problem or identify a type of pH imbalance.

After identifying the type of pH imbalance, students were asked whether there had been enough compensation by the renal or respiratory systems. In the case of metabolic acidosis they were required to distinguish between a high anion gap or a normal gap acidosis in order to make a further diagnosis. The anion gap is the difference between the measured cations and the measured anions in blood (or urine) and the extent of this gap is used to identify the cause of metabolic acidosis.

All of the activities in this laboratory require critical thinking and logic and we believe this laboratory activity was successful in honing these skills. Students responses (Figures 2-6) for this lab activity serve as evidence of this. Ninety-two percent of students agreed that this lab improved their understanding of acid-base imbalance and 88% stated that this lab helped in understanding of the role of the lungs and kidneys in pH regulation. Additionally, 90% students indicated that their quantitative skills also improved following this activity and 94% indicated that they gained understanding of pH imbalances and associated disease processes. Overall, it is clearly evident that collaborative problem-based learning is well received by students and is effective in teaching acid-base imbalances.

Many reports (Barkley *et al*. 2014, Davidson *et al*. 2014) show positive educational outcomes with this type of teaching strategy. Before adopting this new laboratory activity, we taught a lab on a similar topic using the students' own urine (pH changes in urine after imbibing different solutions). Though these students did not do the previous urine-based laboratory, the majority (90%) stated that they would prefer the active learning laboratory activity to the urine-based lab. We believe that the objectives of increasing student engagement, improving critical thinking skills and improving collaberative skills are met by this laboratory activity.

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Literature Cited

Barkley E, Major CH, Cross KP (2014) Collaborative learning techniques: A handbook for college faculty. San Francisco, CA: Jossey-Bass Publishing

Davidson N, Major CH, Michaelson LK (2014) Small-group learning in higher education—cooperative, collaborative, problem-based, and team-based learning: An introduction by the guest editors. *Journal on Excellence in College Teaching*. 25(3&4): 1-6.

Gerlach JM (1994) Is this collaboration? In: K Bosworth and Hamilton SJ. (Eds.), *Collaborative Learning: Underlying Processes and Effective Techniques*, New Directions for Teaching and Learning No. 59:5-14, San Fransisco, USA, Jossey-Bass Publishing

Guyton AC, Hall JE. Textbook of Medical Physiology. 11th edition, 2006, Page 399. Elsevier Saunders.

Myers BE and Dyers, JE (2006) The influence of student learning style on critical thinking skill. *J of Agricultural education*. 47(1) 43-52.

Paul R, and Elder L (2014) The miniature guide to critical thinking: Concepts & Tools, 7th Eds. The foundation for Critical Thinking Publishing

Smith BL, MacGregor JT (1992) What is collaborative learning? In: Goodsell AS, Maher MR, Tinto V. (Eds.), *Collaborative Learning: A Sourcebook for Higher Education*. Pennsylavania State University, USA, National Center on Postsecondary Teaching, Learning, & Assessment publishing.

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