Regional Approach to Musculoskeletal System Instruction May Enhance Student Performance
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Regional Approach to Musculoskeletal System Instruction May Enhance Student Performance

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Abstract
The purpose of this study was to compare instruction effectiveness between a regional approach and a systems approach in teaching the musculoskeletal system to sophomore-level anatomy and physiology students. Exam grades from two consecutive fall semesters were compared. Laboratory materials for the second and third exams were presented using a systems approach first, followed by using a regional approach. This order was used with students (n=139) in the first year of the study. In the second year of the study, the order of presentation was reversed for students (n=144) so that the regional approach was used first, followed by a systems approach. There was no significant difference in the test scores for the first exam between the years, suggesting that there was no difference in overall student ability between years. The overall class average on the third exam was significantly higher (p<0.05), both within year and between years, when the material was presented in a regional approach first. However, correlation analysis did not suggest an increase in individual student performance. Results suggest that spaced repetition and testing of the course material may enhance learning. doi: 10.21692/haps.2018.010

Key words: system-based approach, regional-based approach, musculoskeletal, instruction

Introduction
One of the changes that resulted from the Institute of Medicine’s recommendation for medical education reform in 2003 (Greiner and Knebel 2003) was a more system-based curriculum (Bilderback et al. 2008). Arslan (2014) suggests that a system-based anatomy curriculum has many advantages, in particular the reintroduction of structures at numerous times throughout the academic year. For example, the anatomy of the musculoskeletal system is reintroduced in discussions of cardiovascular and respiratory physiology, which in turn leads to increased student performance in the areas of pathology, clinical medicine, and clinical reasoning. Syed et al. (2014) observed that a systems-based approach for physician assistant students led to strong performance on examinations.

Undergraduate anatomy and physiology courses are often taught using a system-based approach, but like many introductory science classes they have a relatively high rate of students who do not achieve success. While there are few published articles to date specifically on this topic, attrition rates of approximately 50% in undergraduate anatomy and physiology courses have been reported (Hopp 2009, Hopper 2011). The purpose of this study was to determine if a regional-based approach to the musculoskeletal system in the laboratory portion of the sophomore-level anatomy and physiology course would improve student performance.

Methods
Approval for this study was obtained from the Institutional Review Board of the University of Nebraska at Kearney (IRB protocol #062716-1). Students in Biology 225, Anatomy and Physiology I, fall 2016 and fall 2017, were recruited to participate in the study. Biology 225 is the first course in a two-semester sequence and college-level chemistry is the required prerequisite. All students received an invitation to participate in the study and informed consent was obtained via email for the use of student laboratory exam scores and their final grade. Students who consented to participate in the study did nothing differently from other students in the class.

The laboratory portion of the course was divided into three, five-week sections. Each section included four weeks of laboratory activities followed by a laboratory practical exam. The first laboratory practical exam covered basic terminology and organization, movements through membranes, tissues, the integumentary system, basic microscopic and macroscopic anatomy of bones, and types of joints. The second laboratory exam covered the bones and bone features, joints, and muscles of the upper body, and the third laboratory exam covered the bones and bone features, joints, and muscles of the lower body. The laboratory was not dissection-based or cadaver-based; students used skeletons, isolated bones, models, manikins, and illustrations to learn the required structures and were tested using these same materials.

Laboratory exercises for laboratory exam one were identical for students in both years of the study. Laboratory exercises for laboratory exam two in the fall of 2016 were organized using a systems approach while laboratory exercises for laboratory exam three were organized using a regional approach. The order of presentation was reversed in the fall of 2017 in that laboratory exercises for laboratory exam two were organized...
using a regional approach and those for laboratory exam three were organized using a systems approach. Objectives for the first laboratory exercise in preparation for laboratory exam two each year are presented in Figures 1 and 2. Great care was taken to ensure that laboratory exam two and laboratory exam three covered approximately the same number of bones, bone features, joints, and muscles. Students were required to know the origin, insertion, and action(s) of muscles.

All other aspects of the course, including the content, number, and scheduling of lecture exams as well as the timing of fall break and Thanksgiving break relative to laboratory exams, were identical each year. Only the performances of students who consented to participate in the study and then earned a final grade of 70% or higher were included in data analysis. The rationale for this was that the last date of class attendance must be reported for all students who fail a class at my institution. The last date of attendance is important for financial aid considerations. Therefore, some students who have made a conscious decision to change programs of study may complete all aspects of the course so as to document attendance but not put much effort into preparing for exams following the withdraw deadline. The range of scores on the last laboratory exam in 2017, for example, was from 100% to 16%. Therefore, only students who achieved a satisfactory overall grade, suggesting they were putting meaningful effort into preparation, were included in the final data analysis.

Results of exams were analyzed within year using ANOVA and between years using a t-test. In both significance was ascribed for p<0.05. Correlation analysis was also performed on the results of the second and third exams within year.

**Results**

A total of 139 students consented and qualified (earned a final grade of 70% or better) to participate in the study in the fall of 2016 and 144 students consented and qualified to participate in the study in the fall of 2017. There was no difference in student performance on exams one or two between years, but student performance on exam three was significantly higher in 2017 (Table I). Within years, student performance on exam one was significantly lowest both years, but student performance on exam three was significantly higher from student performance on both exams one and two only in 2017. Correlation analysis between student performance in the second and third exams demonstrates a moderate positive correlation each year (2016 r = 0.62; 2017 r = 0.65) but no meaningful difference between years.

**Discussion**

The results of this study suggest that, while presenting the material in a regional approach did not have an immediate impact on student performance, students who were first presented with the material in a regional approach performed significantly better on the next exam than did those students who were presented with the material in a systems approach first. This observation is significant in two ways. First, student performance on laboratory exam one serves as a control in that the course materials were presented in identical fashion both years and there was no difference in student performance on that exam. The observation that student performance on exam one was significantly lowest both years suggests that the act of taking a practical exam allows students to learn how to better prepare to take subsequent practical exams. In addition, the final overall grades for the students were also not significantly different (2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Exam 1</th>
<th>Exam 12</th>
<th>Exam 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016 (n = 139)</td>
<td>80.1 ± 10.1</td>
<td>82.8 ± 9.8*</td>
<td>83.8 ± 10.9*</td>
</tr>
<tr>
<td>2017 (n = 144)</td>
<td>81.2 ± 10.1</td>
<td>84.2 ± 9.3*</td>
<td>88.2 ± 8.9*@</td>
</tr>
</tbody>
</table>

* significantly different from exam 1 within year  
# significantly different from exam 2 within year  
@ significantly different from same exam 2016

**Table 1.** Laboratory practical exam results (average percentage correct ± SD) for Anatomy and Physiology I students who earned a final grade of at least 70% in the course. Exams were identical both years, and material presented for exam 1 was identical both years. In 2016 students were presented with the material first in a systems approach (exam 2) and then a regional approach (exam 3). In 2017 students were presented with the material first in a regional approach (exam 2) and then a systems approach (exam 3). Data were analyzed within year using ANOVA and between years using a two-tailed t-test. Significance was ascribed for p<0.05.
Objectives common to both approaches:

**Learning objectives – bones and bone features of the skull**

1. Identify the following bones and features of the bones of the skull (number of each in parentheses):
   - ethmoid (1)
   - frontal (1)
   - lacrimal (2)
   - mandible (1) - coronoid process, mandibular condyle (condyloid process or head), mandibular foramen, mental foramen, ramus
   - maxillary (maxilla) (2)
   - nasal (2)
   - occipital (1) - foramen magnum, occipital condyle
   - palatine (2)
   - parietal (2)
   - sphenoid (1) – foramen ovale
   - temporal (2) – mandibular fossa, mastoid process, stylomastoid foramen, zygomatic process
   - vomer (1)
   - zygomatic (or malar) (2) - temporal process
2. Identify the following features of the clavicle: sternal (medial) end, acromial (lateral) end
3. Classify the above bones according to their shape: flat, irregular, long
4. Identify the following features of the skull: anterior and posterior fontanels (fetal and infant skull only), jugular foramen, zygomatic arch
5. Identify the hyoid bone

Objectives unique to systems approach:

**Learning objectives – bones of the shoulder, arm, wrist, and hand**

1. Scapula – glenoid cavity (fossa), infraspinous fossa, supraspinous fossa, subscapular fossa, lateral border, medial border, superior border
2. Humerus - (proximal) head (epiphysis), greater and lesser tubercles, intertubercular sulcus (groove), deltoid tuberosity, lateral and medial epicondyles, olecranon fossa, coronoid fossa
3. Radius - (proximal) head, radial tuberosity, styloid process
4. Ulna - coronoid process, (distal) head, radial notch, olecranon process, styloid process
5. Carpals - lunate, scaphoid (navicular), capitate, trapezoid (lesser multangular), trapezium (greater multangular), pisiform, triangular (triquetrum), hamate
6. Metacarpals - first, second, third, fourth, fifth
7. Phalanges - proximal, middle, distal

**Learning objectives unique to the regional approach:**

**Learning objectives – joints of the skull**

1. Identify the following examples of fibrous joints: suture - cranial and facial bones
   gomphosis - tooth fastened into mandible or maxilla
2. Explain the role of dense connective tissue in fibrous joints
3. Identify the following example of a synovial joint and list a specific type of movement possible: “modified” hinge - temporal bone and mandible
4. Explain the role of hyaline cartilage in synovial joints
5. Identify if a joint is synarthrotic or diarthrotic.
6. Identify the four sutures of the cranium: coronal, lambdoid (lambda or lambdoidal), sagittal, squamous (or squamosal)

**Learning objectives – muscles of facial expression and head movement**

1. Identify the following muscles, including their origin(s), insertion(s), and action(s):
   - buccinator
   - epicranius (also called occipitofrontalis)
   - masseter
   - orbicularis oculi
   - orbicularis oris
   - sternocleidomastoid
   - temporalis
   - zygomaticus major
   - zygomaticus minor

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**Figure 1.** Learning objectives for the first week of laboratory in preparation for laboratory exam 2, which covered the musculoskeletal anatomy of the upper body.
Examples of questions common to both approaches:

1. The _____ foramen is a feature of the skull because it cannot be viewed on any individual bone in isolation.
2. When classifying bones by shape, all bones of the face are _____.
3. The _____ of the temporal bone and the _____ of the zygomatic bone join together to form the _____.
4. A "catch-all" term for a prominent projection on a bone is a(n) _____.

Examples of questions unique to the systems approach:

1. A(n) _____ is a rounded process of a bone located at an articulation site. This feature of the humerus rests in a depression called the _____ of the scapula.
2. The spine of the scapula forms a large lateral projection called the _____.
3. The feature on the proximal end of the ulna that forms the “elbow” is the _____.
4. When classifying bones based on shape, all the bones of the wrist as classified as _____ bones.

Examples of questions unique to the regional approach:

1. The muscle that inserts on the coronoid process and ramus of the mandible and acts to elevate the mandible is the _____.
2. The mandibular fossa and mandibular condyle are covered with a thin layer of _____ cartilage. This forms the articular cartilage typical of synovial joints and helps to minimize friction.
3. Based on their anatomy, the sutures of the skull are a type of _____ joint. The two sutures that follow body planes are the _____ and _____ sutures. Based on their degree of movement, these joints are classified as _____.
4. The muscle located in the buccal region that originates on the maxilla and mandible is the _____.

Figure 2. Examples of questions from the students’ laboratory exercises for the first week of laboratory in preparation for laboratory exam 2, which covered the musculoskeletal anatomy of the upper body.
average 84.0 \pm 7.7\%; 2017 average 83.4 \pm 7.0\%).
Therefore, the overall academic performance of students
participating in the study each year was similar. Second, four
of the five laboratory instructors were the same both years,
and the laboratory exercises are organized in such a way that
learning objectives are very clear. All laboratory instructors
strive for consistency between lab sections so that a student
with a conflict (travel for athletics, for example) can attend a
different lab section and have an experience similar to what
he or she would have in the regular lab section. In addition,
grading instructions and criteria for exams were very clear
so as to ensure consistency in grading across instructors.
Therefore, the significant difference in performance observed
on exam three in the fall of 2017, both within and between
years, could potentially be due to the difference in how the
material was presented. Unfortunately, correlation analysis did
not lend much support to this conclusion. Efforts to minimize
variables by keeping all aspects of the class identical other
than presentation arrangement (systems or regional approach)
may have contributed to this. That is, because laboratory
activities were only rearranged and not tailored specifically to
each approach, the potential impact of the regional approach
on student learning was most likely compromised.

One limitation to the study is that not all students who
completed the class were included in data analysis. A notation
of the last date of class attendance is required for all students
who fail a class at my institution, which encourages students to
complete all aspects of the course. Students who have made a
conscious decision to change programs of study, however,
may not put much effort into preparing for exams following
the drop deadline. The range of scores on the last laboratory
exam 2017, for example, was 100\% to 16\%. Therefore, only
students who achieved a satisfactory overall grade were
included in the final data analysis.

Previous experience in an anatomy and/or physiology course
has been shown to have a positive effect on adjustment to
medical school (Miller et al. 2002). The organization of the
musculoskeletal system into a regional approach rather
than the examination of the bones, joints, and muscles
separately is consistent with the approach suggested by
Arslan (2014). It is hypothesized that prior experience with
anatomy presented in a regional approach will not only
improve performance in the sophomore level course but also
ease the transition to professional school. In addition, the
presentation using a regional approach is consistent with
the concept of “spaced repetition,” in which subject matter is
repeated and tested over a period of time (Cohen et al. 2013,
Karpicke and Bauernschmidt 2011, Logan et al. 2011). The
results of this study suggest that using the regional approach,
which required students to think of bone features as muscle
attachments weekly and incorporate those attachments into
joint movements simultaneously, better incorporates spaced
repetition and leads to increased learning when students are
tested on similar concepts in the future.

About the Author
Janet Steele, PhD, is a Professor of Biology and Associate
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anatomy and physiology to sophomores for 25 years.

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