An Evolving Approach to Teaching Comparative Vertebrate Anatomy

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ABSTRACT

Comparative vertebrate anatomy is a discipline that is rooted in a wide variety of other biological sciences including zoology, evolution, and human anatomy. It is commonly taught as part of an undergraduate curriculum with lecture and lab components. There is considerable variation in terms of which topics are emphasized and in which order those topics are covered. This is influenced by instructor expertise and interests as well as consideration of the educational needs of the student population. For instance, emphasis may be placed on taxonomy and evolutionary relationships of specific vertebrate groups or might stress the significance of structure-function relationships. Assessment of student performance is an important component of any course and can vary significantly depending on the balance between examinations and coursework activities. The specific nature of the examinations might involve flagged structures on preserved specimens, text-based questions, or even an oral component. Each of these approaches carries with them a suite of costs and benefits. The breadth and depth of information combined with an abundance of unfamiliar terminology can be intimidating for students and can be a significant barrier to student success. This case study describes how a comparative anatomy course at University of Missouri-Kansas City has been modified since its inception, both in terms of course content and assessment. The general goals were to improve the educational experience for students and to increase engagement through adoption of applied learning techniques. Some of the content changes have related to the timing and inclusion of topics, an effort to better build on preexisting knowledge and application of that knowledge alongside new information gained through observation as part of active group collaboration. Exam scores, course evaluation data, and personal communications from students indicated that in addition to the stated goals there was a reduction in exam-related anxiety.

INTRODUCTION

Comparative Vertebrate Anatomy has foundational roots in a wide range of other science disciplines and because of this broad integration there is no definitive prescription for how to teach it. Some of the key core concepts of Comparative Vertebrate Anatomy include aspects of evolution, structure and function of anatomical structures across biological levels of organization, and morphological development (Danos et al., 2022). Instructors place emphasis on a combination of these and other aspects depending on their personal suite of expertise. The course that is the topic of this current discussion has been taught at University of Missouri-Kansas City (currently BIOLOGY 338L) each Spring since 2014. The course has undergone several annual cycles of modification and reinvention to better align with the academic interests of the students that take the class and to foster a more productive learning environment. Some of the major ways that this class has evolved over time and the ways that they have been implemented will be discussed.

Some changes have allowed a more seamless integration of continuing themes that reinforce the core concepts of the class. Making frequent reference to cladograms of phylogenetic relationships in order to show the distribution of particular anatomical features across taxonomic groups. Other updates have served to fortify the students' sense of community and personal investment in the class, adopting approaches that encourage and reward the use of healthy study habits in service of facilitating increased student success. Great emphasis is placed on cooperative team work and regular review checkpoints.

LITERATURE REVIEW

One of the most frequently cited tools used by educators at all levels is Bloom's taxonomy of cognitive learning objectives (Adams, 2015) which is often represented as a triangle that is internally divided into six stacked levels. The stacked levels represent action verbs related to increasingly complex levels of understanding, with knowledge at the base and Evaluation at the peak. This commonly cited version of Bloom's taxonomy represents one of three domains (the cognitive domain) that were originally described (Bloom, 1956) using nouns, and later revised (Anderson and Krathwohl, 2001; Krathwohl, 2002) to shift the emphasis to verbs; replacing Knowledge with Remember for example. The verbs in the pyramid have numerous synonyms which help educators create measurable learning outcomes. Examples of some of those relating to the core concepts of comparative vertebrate anatomy (Danos et al., 2002) and the learning objectives for the Comparative Vertebrate Anatomy Lab are Name, Identify, and Label at the Remember level referring to the numerous structures encountered. Utilize and relate are examples of verbs that relate to higher levels, for example in utilizing basic dissection techniques and relating the function of one structure to another.

Encouraging a cycle of explaining something new relating to something already known, applying that in a practical way, and discovering something new. Changes to assessment have better reflected the ways in which learning has occurred, rewarding understanding of key concepts and application of theory. This has better allowed students to hone a number of transferrable skills that have practical applications such as effective communication, fine motor skills, pattern recognition, and lateral thinking.

Two of the most successful techniques of the pedagogy at the foundation of this class are the availability of multiple exposures (Chen and Yang, 2020) and scaffolding (Coffman et al., 2023). The similarity in structure between unit one and unit two is intentional as is the way that dissections are carried out for each of the vertebrate specimens. Dissection itself is an essential technique at the core of this class. Dissection serves as both an example of active learning and experiential learning because students must plan and coordinate dissections and then carry them out to an acceptable standard. Vertebrate dissection is also an example of applied learning because practical skills are being developed and unlike on plastic models in the lab, real specimens can potentially illustrate natural variations that may be of interest for certain structures (Kolb, 2015). Active learning techniques are often assumed to be more effective for longer term retention (Kooloos et al., 2020), however more passive approaches like attending lectures, certainly have value and should not be discounted so easily. Variation in spelling of anatomical terms is one of the most challenging aspects of comparative anatomy class for many. The use of word banks is said to be quite rare in anatomy education because of concerns about potential cueing effects (Britson, 2020), although it is unclear to what extent this is actually an issue at higher education levels. One benefit of word bank use for both student and educator is the lack of point reductions from partial spelling errors.

METHODOLOGY

Comparative Vertebrate Anatomy was first introduced in the Spring semester of 2014 and was offered as a special topics class comprising two fifty-minute lectures and a single two-hour lab each week. Lecture content was divided into four modules with the first covering taxonomy, development, and integument. The second module focused on skeletal anatomy and evolution, the third focused on the muscular system, and the fourth dealt with the remaining organ systems. The three lab modules differed in that the skeletal system was included with unit 1. Lab units two and three involved dissection of several vertebrate specimens including frog and cat. A notable theme in student evaluations that first year was that students particularly enjoyed the vertebrate dissections and that they would have liked to have done more of them. Therefore, when the class was officially added to the departmental curriculum in 2015 it was redesignated as a primarily lab-based class with an accompanying recitation session. Time spent in lab was doubled with there now being two two-hour lab sessions each week with a recitation. Recitation sessions are treated differently at different institutions with some being faculty-led and others being

led by a teaching assistant. In this instance the recitation was treated much like a lecture session, providing not only essential background information but also giving an opportunity to discuss concepts and species not accessible in the lab, including animals that it could not be possible to study in a classroom setting. The addition of a recitation session also helped synchronize, balance, and ground the faster lecture-style delivery with the slower but more active lab tasks.

Number of Units

A major change that occurred between 2017 and 2018 was that the number of units was reduced to two resulting in some topics being more extensively discussed in recitation to make more efficient use of the available lab time. Unit one now included the integumentary, muscular, and skeletal systems, and unit two addressed the rest of the organ systems. The role of recitation and lab portions of the class became more clearly delineated with recitation taking on more characteristics of a traditional lecture setting where not only could background material related to lab sessions be introduced and reviewed, but more abstract and diverse topics could be explored beyond the scope of what could be observed in lab.

Order Of Topics

It is common in undergraduate anatomy education to organize course materials in a systems-based fashion whereby entire organ systems are explored as a series of discrete but related units. Undergraduate textbooks tend to be organized in a way that encourages that progression. Graduate anatomy classes and their accompanying dissection guides often take a regional anatomy approach to course progression and take a more integrated approach, studying bones, muscles, blood vessels, and nerves of a specific part of the body at the same time. This better reflects the way that organ systems coexist in the body and better relates to the realities of medical applications. Decisions regarding systems-based versus region-based course progression influence whether dissections follow a sequential or simultaneous pattern. When teaching a course on the history of the Earth we might expect to follow events from most ancient to more recent, and in a similar fashion comparative anatomy education often follows an orthogenetic or linear progression from before the dawn of vertebrate life forward to modern vertebrate diversity. It is very common to begin with a discussion of invertebrate ancestors of vertebrates and to progress through course content to end at mammals, and more specifically humans. This approach allows for inclusion of extinct species along with discussion of their role in an ecosystem and setting them in the context of major global events through time. Students taking the Comparative Vertebrate Anatomy Lab at UMKC reported that they had preferred emphasis to be on extant animals rather than the extinct forms because they better matched their learning goals. Most had recently either taken general biology and human anatomy and most were interested in careers in healthcare fields (a mixture of medical, dental, and veterinary). This was valuable feedback and as of the Spring semester of 2020 the decision to reverse

the direction of course content topic progression was made so that instead of proceeding from fish to mammals it would begin each of the two units with an introduction to mammalian anatomy and then compare those features to each of the other model vertebrate taxa. Following positive feedback this was taken one step further by explicitly reviewing human anatomy at the start of each unit in 2021.

Passive And Active Learning

Learning can occur through passive and active approaches (Kooloos, 2020) and a variety of these teacher-centered and student-centered approaches are used in the Comparative Vertebrate Lab. The weekly recitation conveys a wide variety of information in a format that can be revisited later as a repository of reference material and extends the scope of knowledge beyond what can be encountered in lab. A traditional lecture-hall format works well in that instance and it sets the stage for more active learning to take place in the lab itself. Through combination of recitation and lab sessions students are exposed to multiple approaches by which they can interact with the material. Students listening to lecture presentations accompanied by visual-heavy slide decks, learn by doing by carrying out dissections, and review information by verbally articulating what they have learned to others in their dissection teams. Full participation in dissections during lab sessions is an essential part of the Comparative Vertebrate Anatomy Lab experience. Attendance is taken during lab sessions and students earn participation points for not only being present but actively working as part of their assigned team.

Multiple Exposures and Scaffolding

The lab houses a number of anatomical models showing details of human skin, and thin sections of mammalian skin are examined. Deep to the skin students observe that skeletal muscles are organized into functional groups, and selected muscles are identified on human anatomical models. Next, the muscles that are identified in humans are observed in cat specimens, which have by now been skinned. Students collaborate to complete the dissection and explore the concept of muscle homology. Studying articulated mammalian skeletons in addition to isolated bones allows students to better visualize muscle origin and insertion relationships. After mammals, students in lab move on to studying birds with feathered skin histology, skeletal anatomy, and a pigeon dissection, re-experiencing the same or equivalent structures and reinforcing the knowledge. Recitation gives a broader discussion of avian anatomy and this continues for reptiles, amphibians, and fish along with dissections of bullfrogs, dogfish sharks, and perch fish. This is supported by weekly quizzes that are completed outside of class each week. Unit two begins in a similar fashion as unit one, with a survey of human organ systems followed by comparison with a variety of non-human mammals. Dissection of the selected animals continues in lab throughout unit two in the same taxonomic order as in unit one. Repetition in this fashion is potentially even more effective because students have so many

choices for how they prefer to interact with the course content. Whether alone or in a group, using models or dissections, re-listening to recitation recordings or attempting to verbally explain to a peer, there is something for visual, auditory, verbal, and kinesthetic preferences alike. The multiple exposures approach (Chen and Yang, 2020) is further supported by the use of pre-lab resources that accompany each lab packet. Studying these before coming to lab seemed to greatly enhance satisfaction and effectiveness during lab. Lists of structures and video files showing completed dissections were provided so that students could come to lab well prepared ready to work efficiently. Students were told that practical exams would be using the specimens from a mixture of groups and so students were encouraged to make the most of their time in lab by looking at the dissected animals of other teams. As each unit progressed students showed increased confidence as they gained familiarity with the lab routine and required less prompting and handholding, as is a desired outcome when applying scaffolding techniques (Coffman et al., 2023)

Enrollment Capacity Limit

Enrollment size was intentionally limited to 22-24 students to allow for six or seven dissection teams to comfortably work in the space available. Between 2014 and 2018 the variety of preserved dissection species increased from bull frog and cat to include dogfish shark (a cartilaginous fish), perch fish (a bony fish), bullfrog (an amphibian), pigeon (a bird), and cat (a mammal). This not only better represents the taxonomic diversity of vertebrates but also demands a more challenging array of dissection techniques to properly explore the anatomy of each vertebrate specimen. The tactile differences in integument between the scales of a bony fish and shark are striking and come with them technical challenges that must be overcome in order to produce high quality dissections showing all the necessary structures. Beginning each unit with a synopsis of relevant human anatomy has the benefit of leading students to then apply this knowledge to the subsequent animals. Occasionally there have been course evaluation comments stating that some students would prefer more frequent examinations with shorter units based on less information. However, the units are intentionally as lengthy as they are to encourage review of earlier dissections in the light of more recent information, time to produce and use self-made learning aids, and to draw more meaningful comparisons between related but disparate vertebrate forms. Cramming is discouraged as a strategy and every effort is made to encourage positive study habits such as making effective use of class-time and frequent review and consolidation of knowledge. This approach enables students to experience lab in the spirit of Kolb's learning cycle (Kolb, 2015) of concrete experience, reflective observation, abstract conceptualization, and active experimentation. Information introduced relating to humans as vertebrates becomes more concrete when experienced in the context of examining other mammals like cats and deer, and later in the form of reflective observation of comparable structures in non-mammalian vertebrates like birds and fish. Active experimentation in the form of attempting to locate, isolate, and identify homologous structures in the various vertebrate specimens leads back to

a more concrete understanding why and how structures are the way they are in humans as mammals. Having the professor and Teaching Assistant present in lab helps reassure students that they are correctly identifying structures and are making the necessary connections.

Adoption Of Word Banks

Some students begin the semester with a sense of dread regarding memorization of structures, directional terms, and taxonomic names, and may have been told that this is not an effective way to understand a topic. Rote memorization without deeper contextualization can be problematic but an intentional use of memorization can be effective as a foundational tool on which to support more extensive explanations that lead to understanding. If you don't know what a structure is then it can be difficult to communicate effectively with reference to that structure. Although many students are proponents of using flash cards for study and review, they do not all experience the same level of success. Use of a pre-made set of flash cards might be a smart shortcut for some students whereas for others the very act of making their own flash cards is the most useful part of the process. The more active a role they play in their learning process the better and even those students that preferred to study alone reported that they found building flash cards to be a rewarding experience. Flash cards are however only one way that students deal with large volumes of terminology. Actively connecting together terms from a vocabulary list to produce explanatory paragraphs is a powerful approach, especially when combined with real-time observation of specimens. Being shown direct linkage between what is being done in class and expectations for examinations can help reduce anxiety related to assessment. One of the most common assessment strategies for a Comparative Vertebrate Anatomy lab class is to use times station-based exams. The setup used in this class calls for each student to start the exam at a separate 'exam station' where they will be see a question card with one or more questions relating to a model, specimen, or illustration of some sort. All questions at the station need to be answered within the time allotted for that station and when the time is up they move to the next station. This process repeats until all stations have been visited at least once, or twice in this particular case. The time allowed at each station is typically shorter for the second exposure than the first time around. It is very common for students to have to write their answers out fully for each question, and for spelling errors to carry a point deduction. This is how the class operated from 2014 to 2017 and each semester it was obvious that many of the points being lost on lab exams were due to spelling mistakes and that often times a student would be comfortable identifying a structure but would fall victim to minor spelling errors and would only receive partial credit for what they felt was a correct answer. When this happened, some students expressed as dissatisfaction with their score and reflected as an increased level of anxiety around future exam dates. In the Spring of 2018 to help address this issue, and in an effort to reduce student anxiety and reduce the need to use partial credit, it was decided to start using word banks with terms listed in

alphabetical order. While the use of word banks in anatomy lab exams is certainly not a new concept by any means, it is still relatively uncommon (Britson, 2020). Having a singular large word bank of all relevant terms proved to be an unrealistic goal as there were simply too many terms to fit on a page with a reasonable font size. For that reason, a series of smaller lists of more closely related terms were constructed to accompany each exam station. When the format was explained to students it proved to be the case that some students made the mistake of assuming that since the insistence on spelling perfectly was now reduced that the level of academic rigor was also reduced. This was of course not the case and students that assumed they would have plenty of time to scan the word banks for words they recognized scored much lower than the students that prepared properly. This was only an issue the first time, word banks were used and since that time emphasis has been placed on adequate preparation for lab exams, encouraging learning the correct spelling of all words, and being able to articulate those words as parts of full sentences. It is recommended to think of an answer to a question before referring to the word-bank and to then refer to the word bank before writing the answer on the answer sheet. This has the additional benefit of potentially slowing students down to avoid making mistakes through haste. Providing word banks in exams that are modified versions of structure lists from lab packets has proven very successful in enabling effective efficient class review, exam preparation, and a general reduction in anxiety. One especially effective type of lab exercise had students in dissection teams place flags into specimens to identify each anatomical structure listed in the word-bank and photograph them to create study resources. This helped ensure that none of the structure were overlooked or forgotten about. If a structure proved difficult to locate or if it was something that could easily be confused with something else then this provided an opportunity to seek clarification. Also, if a structure was damaged or absent in a particular specimen then it allowed that to be noted and communicated to others in the class. Students were encouraged to do this first for the specimens that their team had been working on and then to follow the same procedure using the specimens of different dissection teams. This not only reinforced the most important features but it emphasized that natural variation in size and shape is something that should be expected. This exercise formed the core of activity for the pre-exam review. Teams were randomly assigned a dissected specimen of one of the vertebrate groups and were told to indicate with numbers flags a number of structures from their word bank lists. Identifications were listed on a piece of paper and placed beneath the dissection tray. Specimens were exchanged between adjacent teams and the receiving team was tasked with identifying the structures that had been indicated by the original group. The groups could then self-grade their identifications and potentially suggest alternate identifications if the original identification was incorrect. The amount of time with each specimen was timed to help get students exposed to exam-style time constrains, although more time was given than would be the case in an actual exam to allow for more effective communication between team members. When specimens arrived back at the original group there was an opportunity to see how many of their

identifications had been accepted by the other groups, and if other suggestions had been made. This provided a sort of peer review for identifications rather than relying on the instructors alone. Points are awarded for attendance/participation to encourage active involvement in the class, but in-class review activities themselves do not have point values associated with them to ensure that these remained low pressure learning experiences. Weekly online lab quizzes in the style of the examinations carried point values and had a time limit but could be attempted twice before the due date. Students were encouraged to attempt the quizzes under exam-like conditions and to review their results to identify potential areas of weakness in preparation for the examinations.

Final Essay, Final Exam, or Final Project

The original version of the class featured a final project that required library research typical of lecture formatted classes. This allowed for coverage of topics beyond that which could be covered in class because of time limitations. On the other hand, some students expressed concern that the time required for the final essay research was distracting them form studying for the lab exam. It was also unfortunate that there was no opportunity to have students share their reports with others in class before the end the semester. Switching format to a final exam composed of multiple-choice questions modified from previously used unit exam questions allowed for re-exposure to earlier material in the context of spaced repetition. This was coupled with the incentive to drop the score of one of the earlier unit exams if that score was lower than the final exam score. After reflecting on the intended outcomes of the exam it was decided that although it did result in increasing overall grades, some students had resorted to rote memorization and cramming as a way to cope with the stresses associated with the end of semester. The cumulative exam format was abandoned in favor of a more applied and experiential activity which took the form of a brief literature research project that would be expressed as a poster presentation and an associated exam. Assignment instructions guided students to select a topic from a suggested list that they were interested in for further reading, or to find an article which could be related back to course materials. Potential topics were to be submitted for approval as a graded part of their project. On the initial run. Allowing students to suggest their own topics on which to base their project proved to be less successful than had been anticipated as many of the topics lacked imagination or were too simple. Randomly assigning topics from an extensive list proved to be much more satisfying for both students and instructors. Some of the topics selected were extensions of the core course topics, focusing on a particular biological process, anatomical feature, or taxonomic grouping. Other topics had not been explicitly covered in class but served as extensions of course material into published literature and research. Students were also required to suggest five multiple choice questions based on the information contained in their posters. To discourage procrastination submission of a draft version of the poster and suggested questions were

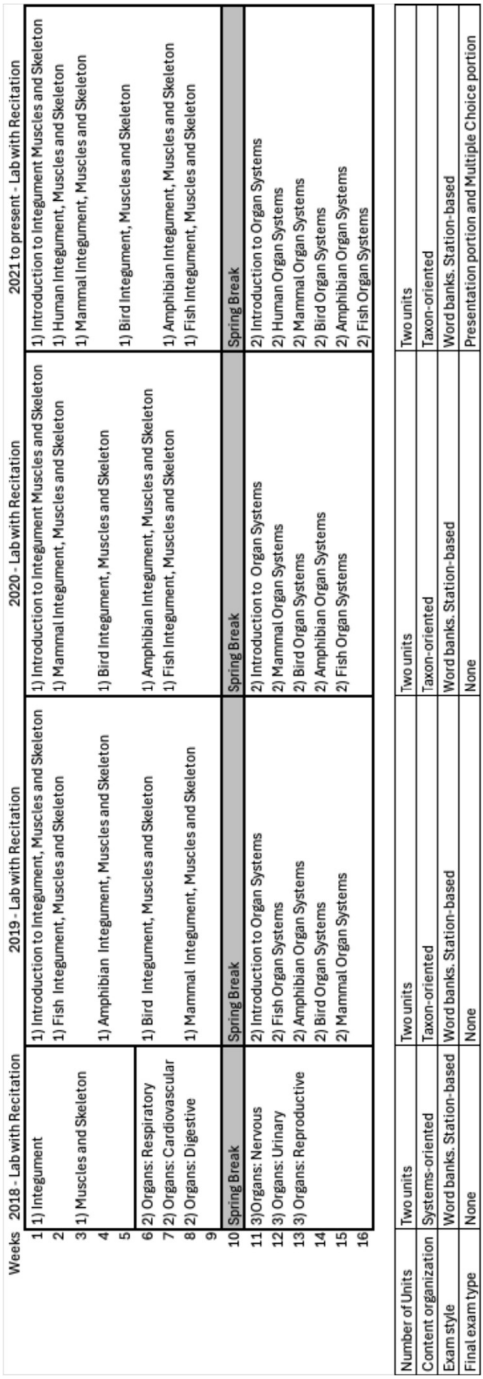
required. Three of the five questions from each student formed the basis for the exam portion of the final. The full list of potential questions was distributed to students along with each of the posters so that students could read through the posters and find the answers as part of their exam preparation. As a final review, students were required to present their posters to the rest of the class and answer any questions that arose. This proved to be a much more effective format in terms of promoting learning as an extension of the main course content.

RESULTS

Figure 1 shows a semester-by-semester comparison and summary of the number of course units each semester as well as those content makeup of each of those units. Also included is information about the number of units, exam style, and final exam type. The number of students each semester is limited to 22-24 students.

Weeks	2014 - Lecture	2014 - Lab	2015 - Lab with Recitation	2016 - Lab with Recitation	2017 - Lab with Recitation
1	1) Taxonomy and Development	1) Taxonomy and Development	1) Taxonomy	1) Taxonomy	1) Integument
2	1) Integument	1) Integument	1) Development	1) Development	
3	2) Skeleton	1) Skeleton	1) Integument	1) Integument	1) Muscles and Skeleton
4			2) Skeleton	2) Skeleton	
5					
6	3)Muscles	2)Muscles	2)Muscles	2)Muscles	2) Organs: Respiratory
7					2) Organs: Cardiovascular
8					
9					
10	Spring Break	Spring Break	Spring Break	Spring Break	Spring Break
11	4) Organs: Respiratory	3) Organs: Respiratory	3) Organs: Respiratory	3) Organs: Respiratory	4) Organs: Nervous
12	4) Organs: Digestive	3) Organs: Cardiovascular	3) Organs: Cardiovascular	3) Organs: Cardiovascular	4) Organs: Digestive
13	4) Organs: Urinary and Reproductive	3) Organs: Nervous	3) Organs: Nervous	3) Organs: Nervous	4) Organs: Urinary
14	4) Organs: Cardiovascular	3) Organs: Digestive	3) Organs: Digestive	3) Organs: Digestive	4) Organs: Reproductive
15	4) Organs: Nervous	3) Organs: Urinary	3) Organs: Urinary	3) Organs: Urinary	
16	4) Organs: Endocrine	3) Organs: Reproductive	3) Organs: Reproductive	3) Organs: Reproductive	

Number of Units	Four units	Three units	Three units	Three units	Three units
Content organization	Systems-oriented	Systems-oriented	Systems-oriented	Systems-oriented	Systems-oriented
Exam style	Multiple Choice and Matching	Fill-in the blank. Station-based	Fill-in the blank. Station-based	Fill-in the blank. Station-based	Fill-in the blank. Station-based
Final exam type	Essay	None	Cumulative Final	Cumulative Final	Cumulative Final



Weeks	2018 - Lab with Recitation	2019 - Lab with Recitation	2020 - Lab with Recitation	2021 to present - Lab with Recitation
1	1) Integument	1) Introduction to Integument, Muscles and Skeleton	1) Introduction to Integument Muscles and Skeleton	1) Introduction to Integument Muscles and Skeleton
2		1) Fish Integument, Muscles and Skeleton	1) Mammal Integument, Muscles and Skeleton	1) Human Integument, Muscles and Skeleton
3	1) Muscles and Skeleton			1) Mammal Integument, Muscles and Skeleton
4		1) Amphibian Integument, Muscles and Skeleton	1) Bird Integument, Muscles and Skeleton	
5				1) Bird Integument, Muscles and Skeleton
6	2) Organs: Respiratory	1) Bird Integument, Muscles and Skeleton	1) Amphibian Integument, Muscles and Skeleton	
7	2) Organs: Cardiovascular		1) Fish Integument, Muscles and Skeleton	1) Amphibian Integument, Muscles and Skeleton
8	2) Organs: Digestive	1) Mammal Integument, Muscles and Skeleton		1) Fish Integument, Muscles and Skeleton
9				
10	Spring Break	Spring Break	Spring Break	Spring Break
11	3)Organs: Nervous	2) Introduction to Organ Systems	2) Introduction to Organ Systems	2) Introduction to Organ Systems
12	3) Organs: Urinary	2) Fish Organ Systems	2) Mammal Organ Systems	2) Human Organ Systems
13	3) Organs: Reproductive	2) Amphibian Organ Systems	2) Bird Organ Systems	2) Mammal Organ Systems
14		2) Bird Organ Systems	2) Amphibian Organ Systems	2) Bird Organ Systems
15		2) Mammal Organ Systems	2) Fish Organ Systems	2) Amphibian Organ Systems
16				2) Fish Organ Systems

Number of Units	Two units	Two units	Two units	Two units
Content organization	Systems-oriented	Taxon-oriented	Taxon-oriented	Taxon-oriented
Exam style	Word banks, Station-based	Word banks, Station-based	Word banks, Station-based	Word banks, Station-based
Final exam type	None	None	None	Presentation portion and Multiple Choice portion

Figure 1. Summary of comparative vertebrate anatomy lab information by semester.

DISCUSSION AND CONCLUSION

Although some aspects of the course have remained unchanged since the original version, much of the structure of the class has been altered significantly to reflect established best practices and personal pedagogical preferences. Increasing the proportion of dedicated lab time devoted to active learning based around dissection teams set the class apart from others in terms of fostering applied and experiential learning that built on the framework provided by the weekly recitation. Introduction of word banks had a noticeable effect in reducing exam-related stress and made it easier to meet the needs of students with special accommodations, and increased grading efficiency, without sacrificing academic rigor. Reorganizing course content both in terms of the number of units and the ordering of topics within those units served to emphasize thoughtful reflection on previously acquired knowledge in the light of practical observations. Changing the format of the final examination to be more like a capstone experience than an exercise in recall paid off better than anticipated and effectively reinforced the learning goals of the class while expanding the scope of the course content within the available time. Switching from a systems-oriented progression to a taxon-oriented progression created opportunities for repeated exposure of previously encountered structures, and opportunities to predict locations of structures in novel specimens based on those previous experiences. Many students have commented on the convenience of taking the comparative anatomy lab after having completed a human anatomy course, and how much of the information is still relatively fresh in their minds at the start of the Spring semester having just taken human anatomy in the Fall.

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