# Pedagogical Enhancements to Animal Anatomy and Physiology: Maintaining and Improving Student Academic Performance in the Discipline[1,2]

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## Abstract

This paper examines systematic improvements that were made to an Animal Anatomy and Physiology course and the extent to which those improvements could be meaningfully associated with an increase in students' academic performance. The changes to the course were enacted with the hope that the curricular enhancements would pay dividends for student success in subsequent coursework within the discipline of animal science. The analysis was designed to uncover the extent to which the changes shared a pattern of association with students' performance in courses that require Animal A and P as a prerequisite. Specifically, we assessed students' ability to maintain or improve on their academic performance as measured by their grades in the prerequisite course and in subsequent courses. Examining the distribution of student grades in Animal A and P and subsequent coursework over several years, a chi-squared test of independence revealed a significant and substantive change in the proportion of students who were going on to maintain or exceed their academic performance, as rated by faculty who were not aware that the systematic changes had occurred. Specific course enhancements are discussed as being particularly promising for high-quality scientific courses with associated lab requirements.

## Introduction

Traditionally, undergraduate veterinary education courses have been replete with lecture-based and teacher-centered models of instruction (Whitney et al., 1993), thereby lacking scaffolded learning experiences to engage students in the learning process (May and Silva-Fletcher, 2015). This is common in higher education as many veterinary education professionals have a high degree of practical knowledge and experience but lack formal teaching preparation highlighting the importance of faculty development (Gordon-Ross et al., 2020). Faculty development leads to instructors providing more meaningful and immersive coursework which engages students in constructing both theoretical and practical content knowledge, and also provides experiential learning opportunities for practical application (Gordon-Ross et al., 2020) (Baillee et al., 2010). This approach has been shown to be more effective for students because of the authentic alignment of the desired learning outcomes with the activities and assessments in the coursework (Biggs and Tang, 2011).

Animal Anatomy and Physiology (Animal A and P) courses are situated to benefit from a more immersive approach on account of their connection to both theoretical and practical content knowledge. As a foundational course, Animal A and P is commonly required as a prerequisite for

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more advanced coursework in the pre-veterinary sciences (Hodgson and Ilkiw, 2017). At Utah State University, Animal Anatomy and Physiology is a prerequisite course for Principles of Animal Nutrition, Animal Health and Hygiene, and Physiology of Reproduction and Lactation. These more advanced courses require students to have a basic level of knowledge in identification of anatomical structures and the relationships of those structures with other surrounding structures and tissues, concepts that are first explored in Animal A and P.

As a prerequisite, Animal A and P is taught in the second year of a traditional four-year college career, allowing students to gain basic knowledge of physiological systems and anatomical structures. As a core science course, Animal A and P includes a lecture portion as well as a lab portion. The lecture portion of the class is designed to discuss Animal Physiology and provides an understanding of the animal body systems and concepts behind how these systems function within the body and in relation to each other. The lab portion of the course is designed to provide students practical exposure to identification of anatomical structures, which provides a foundation for understanding the function and interaction of the physiological systems discussed in lecture. Generally, animal anatomy labs include learning comparative anatomy between many different species of animals. This exposure is critical to understanding variations in physiology because there are variations among animal species that contribute to differences in both pathologies and approaches to treatment.

## Animal A and P as an Academic Experience

The nature of anatomy and physiology labs is largely centered on the memorization of anatomical structures. Understanding more advanced physiological processes in the body in more advanced courses requires students to have a basic level of knowledge about anatomical structures in the context of other surrounding structures and tissues. While many anatomical structures are similar and carry the same name among different species, there are many variations that do not directly translate and create poor transfer in student learning (McNulty and Lazarus, 2018). Species commonly studied include the more popular companion animals, such as dogs and cats, and common livestock species, such as horses, cattle, and small ruminants. The combination of the lecture and the lab in the Animal A and P course is vital for students to prepare for clinical interaction with these species, recognizing the differences in physiological structures between species (Hodgson and Ilkiw, 2017).

## Common Issues with Scientific Labs

A common problem with veterinary education labs is the lack of student involvement in practical activities that lead to increased student competence in the discipline (Dilly et al., 2014). The same is true for Animal A and P. Without a practical, effective, hands-on lab, students do not gain an understanding that allows them to develop competency in the identification of anatomical structures. For example, student lab work can commonly be primarily centered on worksheet completion with pictorial representations of gross anatomy, rather than exposure to physical models (Kellogg et al, 2010). Without practical, hands-on lab experiences, students are not able to understand the relationship that exists between the differing systems. Students who engage with pictorial or video representations of anatomical structures fail to achieve the level of understanding of students who engage with actual cadavers (Theoret et al, 2007). Students also lack enthusiasm with pictorial representation of physical models, whereas hands-on models and cadavers create an atmosphere tangent with real-world situations and students appreciate the aid for learning and the skills developed in cadaver prosection (Gummery et al, 2018). Students are better prepared and more likely to retain the knowledge they gain when they are able to handle and visualize real specimens.

## An Opportunity to Tune the Animal A and P Curriculum

In the spring of 2016, the course ADVS-2200 at Utah State University came under new instructor supervision and an opportunity presented itself to review and improve the curriculum (Varnum et al., 2020). Dr. Karl Hoopes was assigned to take over the course. The lab was identified as the place where changes would be most effective and provide the students with a better and more effective learning experience. In the development of any curricular changes, "The role of the teacher...is to create the culture, structure, and assessment tasks that stimulate student engagement and learner success" (Matthew et al, 2017). The labs were seen as a key area in which curriculum enhancements could take place and several opportunities for enhancing the lab curriculum were identified.

## Five Systematic Course Enhancements

Given the opportunity to improve this learning experience on behalf of students, several specific enhancements were implemented in the lab following the Spring 2016 semester. The specific aims of these changes were to increase student competence in identification of key anatomical structures as they relate to animal health, to help students gain an understanding of comparative anatomy between species, and to improve retention of the knowledge gained. These outcomes are highlighted in previous work as being essential for student preparedness in the discipline (Jaarsma et al, 2009). The following sections outline important elements of the five changes that were made as we worked towards an enhanced student experience.

### *1. Instructor Collaboration*

To prepare for lab curriculum changes, Dr. Karl Hoopes created a community of practice, also known as a learning circle, to crowdsource relevant enhancements that might be made to the course. Consultants that were utilized within the learning circle included the chair of the curriculum committee for the ADVS department (Dr. Kerry Rood), the School of Veterinary Medicine anatomist (Dr. Briedi Gillespie), four GSTAs, and 2 UTFs. Nick Robl, DVM (a graduate student at the time) was identified among the pool of GSTAs and given the task to coordinate the changes that were being made with the other GSTAs and UTFs.

The learning circle provided 1) needed insight into what expectations were realistic for undergraduate students, 2) valuable experience of students in previous labs, and 3) an opportunity to enhance the teaching and learning of the GSTAs and UTFs. Initially meetings were held as needed, with all consultants making contributions to the experience. As a plan was developed and implemented, the learning circles, which occurred periodically, were streamlined to consist of Dr. Karl Hoopes, Dr. Nick Robl, and the other GSTAs and UTFs.

*2. Alignment of Learning Outcomes*

An emerging theme in veterinary education is designing a student-centered course that initially defines what the students should be able to do by the end of the course (Hodgson and Ilkiw, 2017). Backwards design is the process of identifying learning outcomes for students and then aligning those learning outcomes to the content, assignments, and assessments in the course (Wiggins and McTiche, 2005). Course design with "An outcomes focus helps identify essential, underpinning knowledge and helps create priorities for inclusion of content" (May and Silva-Fletcher, 2015). For this course, the process began with establishing course level learning objectives, lab section objectives, and then moved to defining the lab schedule and creation of the new course syllabus (Nilson, 2010). The lab portion was divided into sections based on body systems. The sections were scheduled to overlap with lecture material to provide continuity for students. Additionally, learning outcomes were created for each section of the lab. These learning outcomes were also aligned with learning outcomes in the lecture portion of the class. The lab-based learning outcomes consisted of lists of anatomical structures and locational terminology of the targeted system for each course period. The learning outcomes were made available to students via the Canvas learning management system (LMS) prior to each lab. In this new format, students were expected to familiarize themselves with the learning outcome and terminology in advance of each class. In addition to the learning outcomes, students were provided with an online presentation that included images and description of the structures and terminology in the learning outcomes. Providing the learning outcomes to students before each class has been demonstrated to be an effective strategy with adult students (e.g. veterinary students), as it signals the expectations and the road map framework for the upcoming class (Knowles, 1968). In other words, learning objectives makes explicit the purpose of a lesson that would otherwise only be implicit.

*3. Experiential Enhancements*

It is no longer satisfactory for instructors to solely plan and deliver lectures; instead, instructors "are also expected to develop course materials and create learning situations that encourage students to actively engage in learning" (Jaarsma et al., 2009). To enhance the quality and experiential relevance of the lab and to contribute to student retention of the course content (Kolb, 2015), animal cadavers and prosections were incorporated into the class (Sprunger, 2008). Several dog and cat cadavers were procured and made available to the students. GSTAs were trained to dissect the cadavers focusing on key anatomical structures. Some cadavers displayed particular muscle systems while others focused on nerves, bones, or organs. Additionally, students were provided the opportunity to dissect smaller specimens. These variations contributed significantly to what we perceived as higher levels of student engagement and mastery of the learning outcomes. Indeed, as has been shown in previous research, the acquisition of practical skills during the training program is an area of "major concern" for veterinary students and program graduates (Knowles, 1968). More importantly, the structure of the labs also shifted to a learner-centered format of inquiry-based problem solving, in contrast to the previously more didactic approach: "In a constructively aligned [veterinary medicine] course, the learning activities meaningfully illustrate and allow exploration and practice of desired skills and knowledge, enabling students to construct meaning through discovery and actions rather than simply receiving information from the teacher" (Matthew et al., 2017). Accordingly, lab stations were restructured such that for each specimen, students were provided several questions to answer with the information and diagrams provided in the online laboratory material. This question-based, problem solving format facilitated discussion among students and more thorough observation of specimens compared to what would have been possible using two-dimensional diagrams (May and Silva-Fletcher, 2015) (Al-Khalili et al., 2014). Students were provided with answers to the question at the end of labs so that they could correct mistakes and ask further clarifying questions, all of which contributed to the experiential immersion of students in the lab.

*4. Enhanced Training*

In order to address the common issue of scientific labs being either too short or too shallow in content (Dilly et al., 2014), a new training protocol was designed to enrich the expertise of the GSTAs (Dalgaard, 1982). Dr. Hoopes took on the responsibility of training and development of the GSTA's. Dr. Robl was assigned as the lead GSTA with 3 additional GSTAs helping. As the semester progressed, each GSTA was assigned to develop presentation materials corresponding to the weekly lab objectives. These were assigned according to the strengths and knowledge of each of the GSTAs. Dr. Robl set up each lab, selecting which cadavers, specimens, and models to use. He also instructed the other GSTAs in teaching techniques and about the anatomical systems with which they were unfamiliar. With each GSTA assigned a lab section to teach, the UTFs were utilized in setting up the lab, answering questions during lab, and cleaning up at the end of the day.

*5. Calibrating Student Expectations*

Another important element of these curricular upgrades was the process of increasing student expectations for the required workload in the lab (Tinto, 2012). The weekly objectives sheets defined the expectations for the amount of memorization and identification of anatomical structures that would be required for success in the course. These objectives greatly expanded the detail and amount of memorization required by students in labs from previous years, as well as their expectations for the week's work. Setting higher expectations for student performance has been shown in previous research to have a positive influence on student perceptions of the value of a course. For example, "Research conducted in nearly 500,000 classes across more than 300 institutions revealed that instructors are more likely to earn high student ratings of instruction when their students say their teachers challenged them and had high achievement standards" (Benton and Ryalls, 2016). While the basic outline of the lab stayed the same, PowerPoint presentations were also made available on the LMS prior to class to allow students to further preview what to expect in the coming class session. Scaffolding for these expectations surrounded both the actions that students would be required to take in the lab and also the dividends that these outcomes would produce in student preparedness for continued study in the discipline. Defining a value-based rationale for classwork in this manner is something shown in previous research to be particularly empowering, as it mediates student motivation for participating in something they may otherwise find uninteresting (Reeve et al., 2002). In this way, the course enhancements surrounding student expectations were designed to support their motivational development not only as students in this course but also as students in the discipline.

## The Present Study

Following the implementation of all the aforementioned systematic enhancements, we capitalized on the opportunity to scope the extent to which such changes could be shown to have a significant association with student academic performance in subsequent courses. Specifically, the purpose of this study was to determine if, after the systematic changes to ADVS-2000, there was a significant increase in student performance in the courses that require ADVS-2200 as a prerequisite (hereafter referred to as "outcome courses"). The theory of change for this design is grounded in the hope that the systematic changes made in ADVS-2200 would lead to improved student comprehension in Animal A and P that would pay dividends in subsequent coursework (manifest as increased academic performance in three outcome courses).

## Method

### Participants and Courses of Interest

ADVS-2200 is a course that is typically taken during the second year of a four-year Animal, Dairy, Veterinary Sciences bachelor's program at Utah State University. For the current study, enrollments for 761 undergraduate students who completed the course between Fall 2012 and Fall 2018 were identified for analysis. The primary data of interest were these students' grades in ADVS-2200 and their grades in three outcome courses for which ADVS-2200 serves as a prerequisite: ADVS-3000 - Animal Health and Hygiene; ADVS-3500 - Principles of Animal Nutrition; and ADVS-4200 - Physiology of Reproduction and Lactation. Approval to conduct this archival research project, in which student data were used in retrospect, was received from the Institutional Review Board.

### Hypothesis and Design

To determine if systematic changes to the curriculum and structure of ADVS-2200 were associated with increased student performance in subsequent outcome courses, a chi-square test of independence was planned. Specifically, a matrix of student performance in several outcome courses was designed to reveal if there was a significant increase in the number of students who went on to achieve grades in outcome courses that were at least as good as the grades they earned in ADVS-2200. Based on the systematic changes made to ADVS-2200, the hypothesis of this study was that, following the systematic changes to ADVS-2200, there would be a significant increase over previous years in the number of students earning grades in outcome courses that were at least as good as students' earned grade in the prerequisite course (see Table 1).

**Table 1 (con't). Evidence of Teaching Effectiveness from Students and Alumni**

| Term / Year | Description of Curricular Enhancements |
|---|---|
| Spring 2012 | Previous Instructor |
| Spring 2013 | Previous Instructor |
| Spring 2014 | Previous Instructor |
| Spring 2015 | Previous Instructor |
| Spring 2016 | Co-taught with Previous Instructor (no changes) |
| Spring 2017 | • Enhanced integration of experiential learning into the course lab<br>* Increased student expectations<br>* Effective training of GSTA/UTF<br>* Increased use of animal cadavers and models<br>• Use of Canvas to post lab information for student preparation<br>* Module structure used in Canvas for easy navigation<br>* Lab information placed on module overview pages<br>* Formative quizzes included to be taken pre-lab<br>* Lab terms listed to assist in student recall |
| Spring 2018 | • Utilizing Canvas to align course outcomes to assessment<br>* Outcomes made available to students and aligned with lab material<br>* Included in Canvas module overview pages for ease of use |

The three outcome courses were taught by instructors that were not aware of or involved in the teaching and preparation of the ADVS-2200 course itself and who were unaware of the intention to carry out the present study. As previously stated, the hope was that the systematic changes made in ADVS-2200 would lead to improved student comprehension of Animal A and P that would pay dividends in student performance in subsequent coursework. Importantly, the individuals grading these outcome courses were independent assessors of student academic proficiency, having little knowledge of the systematic changes that had been made to the prerequisite course. Additionally, when informally polled, the instructors of these courses indicated that no significant changes had been made in their curriculum and instructional practices during the period of time in question that would have led to significant shifts in student grades compared to earlier years of student performance.

This design emerges from the non-experimental nature of student enrollments; students are generally not randomly selected and randomly assigned to take coursework in conditions of experimental treatment and control. Instead, our ability to answer the question in mind was constrained by the in vivo nature of the curriculum changes and a post hoc decision to conduct the present investigation. Speaking to this point, it is worth noting that a great deal of research pertaining to the Scholarship of Teaching and Learning (SoTL) is conducted in a fashion that merely hints at (or estimates) a causal relationship between systematic curricular changes and measured student outcomes (Felten, 2013). As such, the goal of the present study was not to demonstrate an irrefutable link between the systematic changes and subsequent student outcomes, but to demonstrate a plausible link that might inform teaching practice in other veterinary programs.

## Results

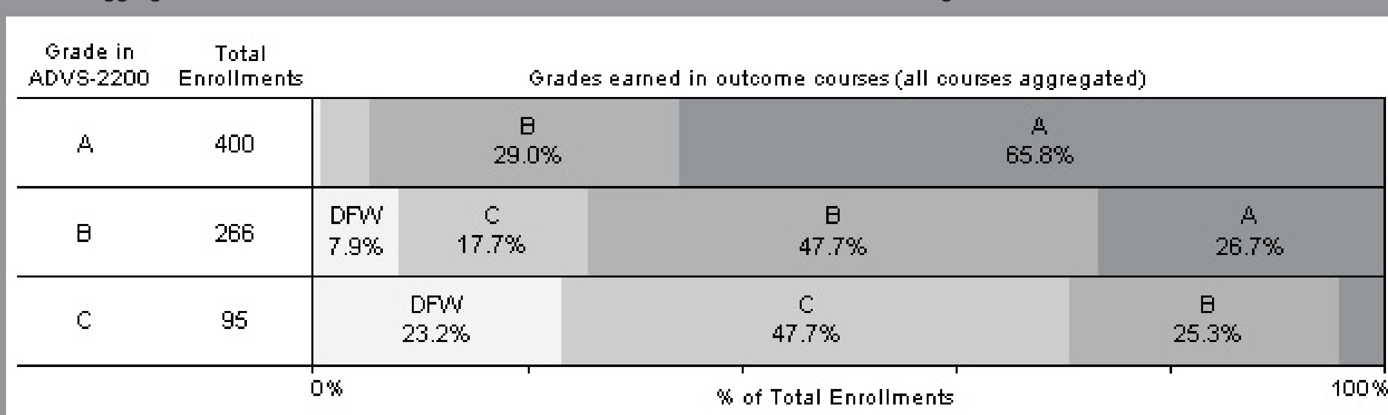
First, a descriptive analysis was run to demonstrate a relationship between grades in ADVS-2200 and student grades in outcome courses. Table 2 shows this relationship, with a higher proportion of students earning A's in outcome courses after earning an A in ADVS-2200.

Next, Table 3 shows distributions of students' final grades in the outcome courses, year by year. Curriculum changes began in 2017 and outcome course grades displayed in the table were all earned subsequent to students' completion of ADVS-2200. A higher proportion of students earning A's and B's in outcome courses is visibly notable in Table 3 for students who participated in the enhanced curriculum experience provided in the prerequisite course during 2017 and 2018 (compared to all previous years). It is worth noting that attrition rates of students leaving ADVS-2200 and entering the outcome courses did not meaningfully shift during the years in question. As such, the results displayed in Table 3 are a meaningful portrayal of improvements in students' academic performance associated with the changes in curriculum.

To conduct the chi-squared test of independence, student grades were organized into two main categories: (1) those whose grade in the outcome course was greater than or equal to their grade in ADVS-2200 and (2) students whose grade in the outcome course was less than their grade in ADVS-2200. As shown in Table 4, a dramatic shift in the proportions of students in these two categories took place following the systematic changes made to the curriculum and instructional design of ADVS-2200 (enhancements occurred during Year 2 and Year 3).

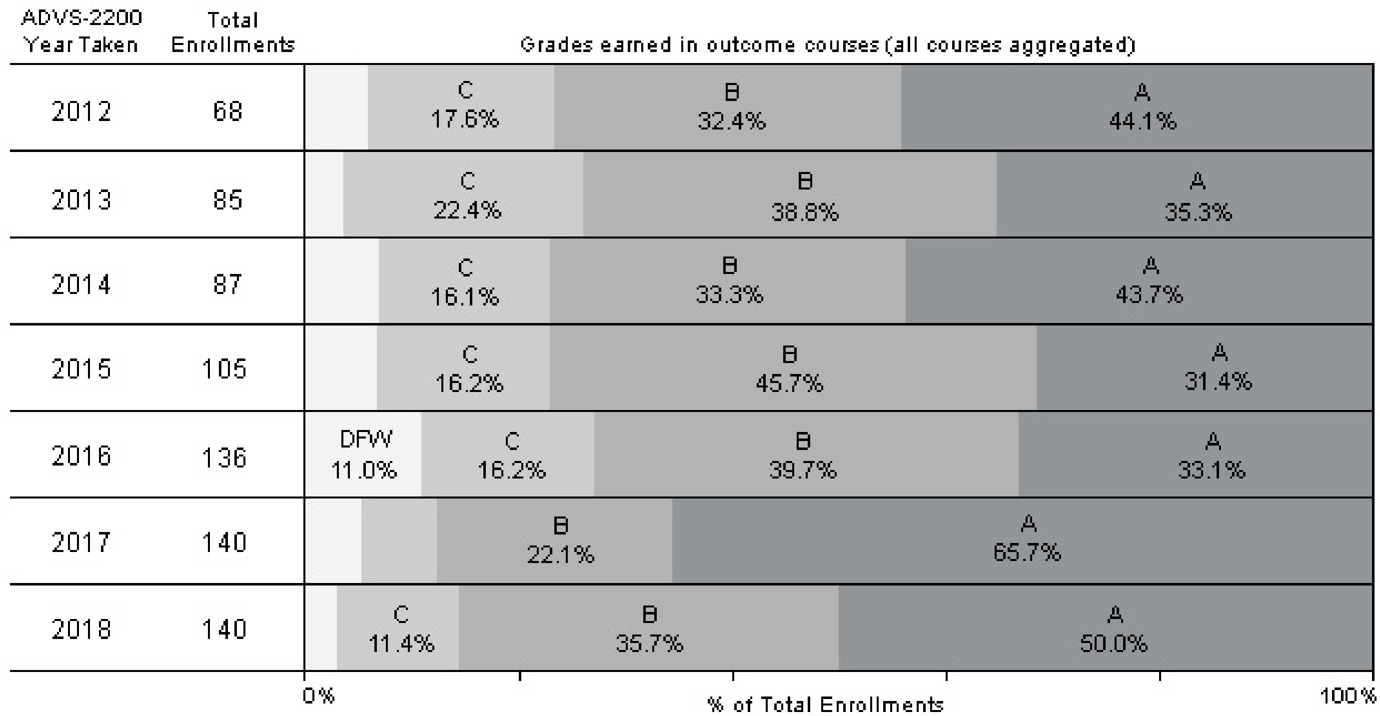
A chi-squared test of independence was run to compare the proportion of students earning grades in outcome courses that were greater than or equal to their grades in the prerequisite course, year over year. For the data displayed in Table 4, a significant chi-square test of independence was found, X2 (11, N= 761) = 116.45, p <.0001. The adjusted residuals for this test are displayed in Table 5. Of particular note are the elevated counts of students receiving grades in outcome courses that were greater than or equal to their prerequisite grades across both Year 2 and Year 3. Following the changes in Year 2, we see a significant increase in the number of students that earned A's and B's in ADVS-2200 who also went on to receive grades greater than or equal to their prerequisite grade. In Year 3, higher-than-expected counts were seen for students who maintained or outperformed their grade in the prerequisite

**Table 2. Aggregated Distributions of Student Grades in Outcome Courses for Students Taking ADVS-2200 from 2012 to 2018**




Note. If students earned grades lower than a C in ADVS-2200 (grade D or F) or if they withdrew before completing the course (grade W), they were not eligible to enroll in the outcome courses.

**Table 3. Aggregated Counts of Grades Earned in Outcome Courses, Year-by-Year**




Note. The curriculum changes described in this study were experienced by students who took ADVS-2200 in 2017 and 2018.

course, across all three grade ranks (A, B, and C).

## Additional post hoc analysis

As one can see in Tables 3, 4, and 5, a significant shift in the quality of student performance in courses requiring ADVS-2200 as a prerequisite took place in 2017 and 2018. Due to the impressive nature of these findings, we wanted to be sure that these improvements were, in fact, isolated in the ADVS courses that require ADVS-2200 as a prerequisite and had not occurred in other courses in the department at the same time. In other words, we wanted to be sure that a similar upward shift in student performance was not widely occurring in the department, for example, as a result of prominent trends in the discipline that would have produced similar pedagogical improvements as in ADVS-2200. Accordingly, we look at all students' performance in 3000- and 4000-level courses that were similarly situated to the outcome courses for ADVS-2200 and that students in the same ADVS cohort would have been taking at the same time.

Our analysis of all similarly situated 3000- and 4000-level courses in the department revealed no meaningful shift in grading during the time period in question, as shown in Table 6. Although fluctuations are apparent in the post hoc analysis of cohort-comparison courses, a chi-squared test of independence revealed that none of these shifts represented a significant shift from year to year, X2 (18, N= 1151) = 13.03, p = 0.789.

**Table 4. Percentage of students earning grades greater than or equal to their grade in ADVS-2200, compared to percentage of students earning grades less than their grade in ADVS-2200**

| | | Grade in outcome course was: | |
|---|---|---|---|
| ADVS-2200 Year Taken | Grade in ADVS-2200 | Greater than or equal to grade in ADVS-2200 | Less than grade in ADVS-2200 |
| 2012 - 2015 | A | 52.88% | 47.12% |
| | B | 44.00% | 56.00% |
| | C | 52.27% | 47.73% |
| 2016 | A | 38.98% | 61.05% |
| | B | 29.73% | 70.27% |
| | C | 46.15% | 53.85% |
| 2017 | A | 82.93% | 17.07% |
| | B | 71.93% | 28.07% |
| | C | 73.68% | 26.32% |
| 2018 | A | 84.31% | 15.69% |
| | B | 86.11% | 13.89% |
| | C | 84.38% | 15.63% |

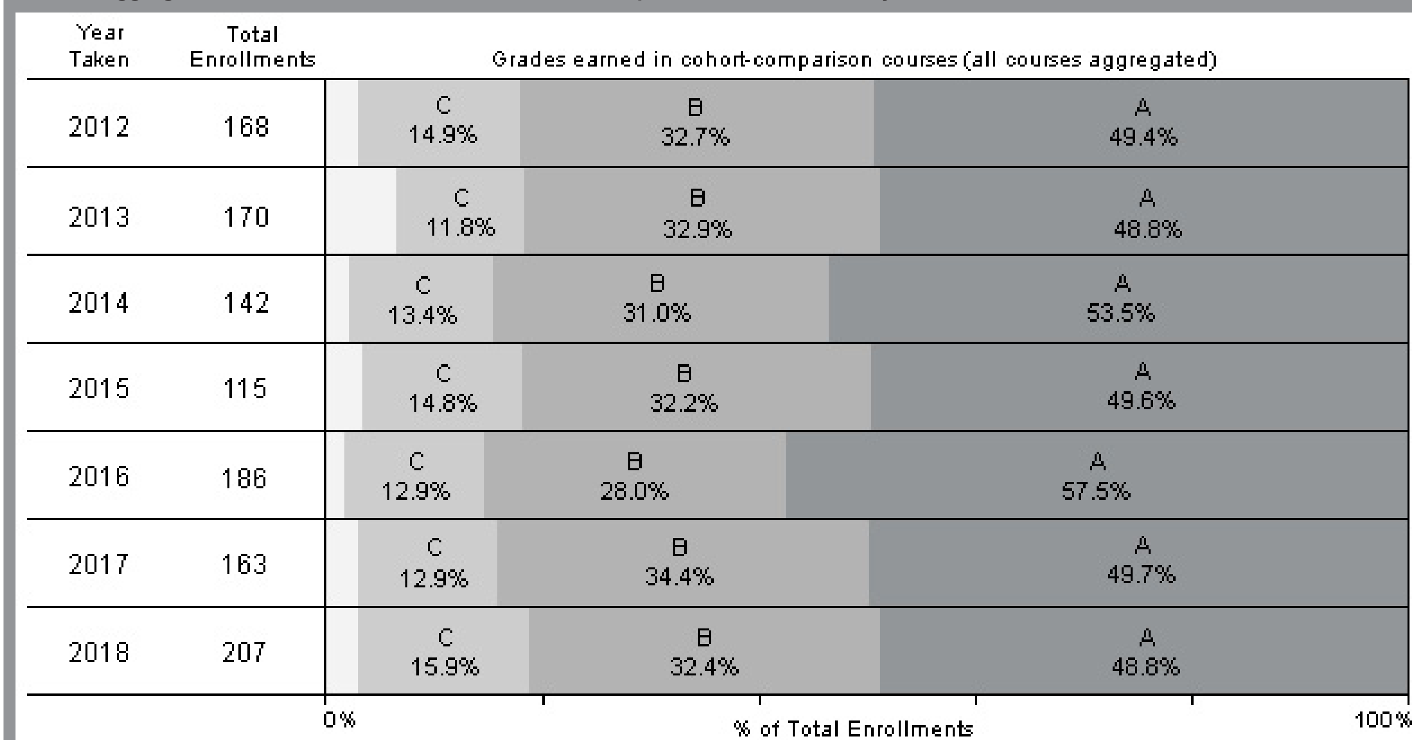
## Discussion

This study was designed to reveal the extent to which, following curricular enhancements in an Animal Anatomy and Physiology lab, there would be a significant increase over previous years in the number of students earning grades in outcome courses that were at least as good as students' earned grade in the Animal A and P course. The approach examined proportions of earned grades in three courses that required Animal A and P as a prerequisite. As displayed in Tables 4 and 5, significant increases were seen

Table 5. Observed and Expected Counts for the Chi-Squared Test of Independence, with Adjusted Residuals (Year by Year)

| | | Observed Counts | | Expected Counts | | Adjusted Residuals | |
|---|---|---|---|---|---|---|---|
| | | Grade in outcome course was: | | Grade in outcome course was: | | Grade in outcome course was: | |
| ADVS-2200 Year Taken | Grade in ADVS-2200 | Greater than or equal to grade in ADVS-2200 | Less than grade in ADVS-2200 | Greater than or equal to grade in ADVS-2200 | Less than grade in ADVS-2200 | Greater than or equal to grade in ADVS-2200 | Less than grade in ADVS-2200 |
| 2012-2015 | A | 96.00 | 95.00 | 107.42 | 83.58 | -1.92 | 1.92 |
| | B | 45.00 | 70.00 | 64.68 | 50.32 | -4.01 | 4.01 |
| | C | 18.00 | 21.00 | 21.93 | 17.07 | -1.30 | 1.30 |
| 2016 | A | 29.00 | 58.00 | 48.93 | 38.07 | -4.58 | 4.58 |
| | B | 10.00 | 26.00 | 20.25 | 15.75 | -3.53 | 3.53 |
| | C | 6.00 | 7.00 | 7.31 | 5.69 | -0.74 | 0.74 |
| 2017 | A | 61.00 | 14.00 | 42.18 | 32.82 | 4.61 | -4.61 |
| | B | 36.00 | 14.00 | 28.12 | 21.88 | 2.32 | -2.32 |
| | C | 10.00 | 5.00 | 8.44 | 6.56 | 0.82 | -0.82 |
| 2018 | A | 39.00 | 8.00 | 26.43 | 20.57 | 3.81 | -3.81 |
| | B | 55.00 | 10.00 | 36.56 | 28.44 | 4.82 | -4.82 |
| | C | 23.00 | 5.00 | 15.75 | 12.25 | 2.81 | -2.81 |

Table 6. Aggregated Counts of Grades Earned in Cohort-Comparison Courses, Year-by-Year



for students' academic performance in outcome courses following the enhanced experience within the lab, which included greater intentionality on the part of the instructor in the alignment between course activities, student expectations, and course outcomes. The overall findings are particularly meaningful because they indicate that the new structure of the Animal A and P course and lab were more effective at helping students to maintain or improve their academic performance in the discipline.

As stated before, the foundational nature of the Animal A and P course means that knowledge students glean from this course is essential to their performance in more advanced coursework. As a required course, Animal A and P is an academic gateway into students' love for the discipline, knowledge of fundamental concepts, and engagement with faculty who share a similar passion for animal science. As such, it is not surprising that, following systematic enhancements made to this prerequisite course, students were more ably situated to perform well in subsequent coursework, maintaining or exceeding their academic performance in the prerequisite course. Based on the instructor's experience, the improvements in student performance in outcome courses may have resulted from several different factors or a combination thereof, as follows.

Of all the enhancements made to this course, the use of real specimens in the lab may have been the most instrumental in aiding an increased understanding of anatomy amongst students, facilitating an improvement in students' understanding of more advanced material in subsequent classes. The experiential enhancements that were vital to the success of the students included the practical use of cadavers and animal models. The instructors have found that when students are able to physically inspect, handle, and manipulate animal models and cadavers, their understanding and retention of that knowledge is enhanced. Additionally, in combination with these developments, requiring students to answer questions and solve problems may have improved students' ability to learn independently. Because of the meaningful and immersive nature of the experience compared to the use of two-dimensional diagrams, students were more able to understand relationships with corresponding systems and tissues. Anatomic structures are not just names or words on paper or computer. The structures have meaning and a function. As explained by Matthew, Norris, and Krockenberger in Veterinary Medical Education: A Practical Guide, "Being an effective veterinarian requires integration of knowledge, skills, and professional attributes. Therefore, effective teaching of veterinarians requires the integration of theoretical and practical material, and development of professional attributes, to achieve the intended learning outcomes" (Matthew et al., 2017). The use of animal cadavers and models allows for this practical understanding to be developed through direct experience and inquiry-based problem solving, in contrast to a more didactic approach that has become too common in the discipline.

Secondarily, the increased expectation from students in the laboratory seemed to be an essential aspect of the gains produced by the new approach to the course and lab (22). Enhanced articulation of expectations for student performance may have encouraged an improvement in study habits and independent learning, which may have transferred easily into enhanced student performance in subsequent courses. Calibrating student expectations allows students to not only develop realistic goals for the coursework but also mentally forecast the effort required to meet those goals (Reeve et al., 2002). Students are excited and willing to learn and given the opportunity will rise to the occasion. Care should be taken to not expect too much at one time, and show willingness to provide support and when students hit learning barriers (Harland et al., 2003). However, students are often capable of much more than even they would expect when given a chance to show what they can do.

From a pedagogical perspective, the alignment of course and laboratory learning outcomes may have streamlined the curricular structure contributing to an improvement in the retention of information. Alignment of learning outcomes ensures that teaching objectives are well defined and the path to meeting those objectives is clear in the mind of the instructor (Benton and Ryalls, 2016)(Jaarsma el al., 2009). Almost as important, clearly stated learning objectives ensure that students are familiar with the goals of the lab and can work towards those goals in collaboration with the faculty and teaching assistants. Transparency in learning objectives and outcomes to students allow them to see the bigger picture of the necessity and importance of the course material. This kind of motivational mediation has been shown to produce an autonomy-supportive environment that enhances student well-being (Reeve et al., 2002).

As a final note on how the course enhancements contributed to student performance, instructor collaboration and enhanced training for teaching assistants seemed essential for the development and success of the lab setting. Training for teaching assistants has been shown in previous research to be effective (Dalgaard, 1982). The enhanced training of teaching assistants in this study seemed vital to ensuring competency and quality of instruction to students in the scientific lab. Additionally, getting stakeholders input into what students should be learning allowed instructors the opportunity to see past their own responsibilities and help prepare the course to develop students for future endeavors in school and in careers. From a reflective perspective, these activities were essential aspects of the developmental process that made the course enhancements possible, ultimately helping students to perform more successfully in the subsequent academic experiences in the discipline.

## Limitations and Implications for Future Research

The post hoc nature of the approach used in this study means that our ability to draw specific connections between all of the systematic enhancements that were made, and the increased academic outcomes achieved by students is constrained. While the improvements in student performance over the previous years of the course clearly coincided with the structural improvements made by the current instructor, a retrospective analysis prevents our ability to distinguish the precise mechanisms that helped students achieve gains in their subsequent coursework. For example, was students' subsequent academic achievement a product of improvement in study habits empowered by the new course structure or was it a result of the actual improvements themselves in helping students understand core concepts of the discipline? The answers to such questions can only be hinted at by the data and based on our impressions of how students reacted to the changes in the course. We were able to show in an additional post hoc analysis that enhanced student performance was isolated in the department to courses that required ADVS-2200 as a prerequisite. While this is a meaningful and supportive piece of evidence, future research could focus on expanded methods that isolate cause/effect relationships between systematic course enhancements similar to those discussed here and improved student academic performance.

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