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ORIGINAL RESEARCH

A Quantitative Analysis of Four Undergraduate Human Anatomy Laboratory Curricula: Approaches, Identified Structures, Concepts, and Thematic Emphases

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Abstract
Human anatomy is a foundational course thatserves diverse pre-professional health care majors. However, limited information is available on the teaching approaches, content, and thematic emphases of this course at the undergraduate level when compared with that of medical and other graduate schools. Herein, we document and quantitatively evaluate the laboratory curriculum of four undergraduate human anatomy courses in the USA. For each course, we assess the total number of structures (terms requiring identification during an exam), concepts (terms requiring an explanation), and clinical applications. To facilitate further assessments, we also compare the content distribution of each course with that recommended by the American Association of Clinical Anatomists (AACA). Two courses followed a regional approach emphasizing the use of human cadavers, while the other two followed a system-based approach and used plastic models and non-human cadaveric materials (e.g., cats and sheep). The total amount of information presented to students differed significantly among curricula. The majority of terms (65–88%) taught to students referred to the identification of anatomical structures whereas clinical applications were rare (< 1.3%). Courses using a regional approach expected students to learn as much as twice the number of terms than those following a system-based approach. Functions, innervations, origins, and insertions of muscles are only included in the curriculum of the courses following a regional approach. The proportion of terms devoted to each anatomical module in all curricula was significantly different from each other, as well as from that of AACA recommendation. We discuss these differences in the curriculum, the challenges and limitations inherent with each teaching approach, as well as in the teaching materials used among the curricula. These quantitative analyses aim to provide insightful information about the structure of the undergraduate human anatomy laboratory curriculum and may prove useful when redesigning a course.

Keywords Human anatomy curriculum · Quantitative analysis · Undergraduate education

Introduction

Human anatomy is a cornerstone course for many pre-professional health care majors, as well as for medical schools and other graduate programs. While graduate-level courses are often the subject of pedagogical research and analyses [1–4], assessments on undergraduate human anatomy programs are limited [5]. Therefore, the goal of this study was to evaluate the content of the laboratory curricula in the undergraduate human anatomy courses offered at four 4-year institutions in the USA where we teach or have taught. We chose to assess the laboratory curriculum because, in addition to complementing the theoretical background of the lecture, it offers more opportunity for effective learning throughout hands-on activities, usually in small class sizes.

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Human anatomy at our institutions is often considered a service course for several majors including nursing, occupational therapy, physical therapy, and physician's assistant. Whereas students seeking a medical degree might benefit from taking an undergraduate human anatomy course, it is not required at some US universities [5], including those that are the focus of this study. We were motivated to conduct an assessment of the laboratory curriculum given the importance of anatomy for the understanding and application of other disciplines and for the obvious differences in the content, organization, resources, and pedagogy of this course offered among our institutions (Table 1). For example, at two universities, the course uses plastic models and non-human cadaveric materials (e.g., preserved cats and sheep organs) in a system-based approach (SBA), which presents the content in relation to major body systems such as circulatory, respiratory, etc. At the other two institutions, the course emphasizes the use of human cadavers in a regional approach (RA), which presents structures and systems relative to a body region (e.g., head and neck, thorax, upper limb, etc.). The courses compared also vary in format (integrated or not with a lecture), availability of electronic resources (e.g., online homework), implementation of peer-teaching approaches, and training and personal emphases of the instructor. Although these four courses do not represent all possible teaching approaches, content, and thematic emphases used across US undergraduate institutions, available data indicate that similar programmatic approaches are commonly employed [6–8].

It is not surprising that anatomy curricula vary among institutions, but it is likely that some common approaches to teaching anatomy might be more desirable. For instance, it is common to teach human anatomy using non-human models, such as domestic cats or fetal pigs, because preserved specimens are readily available and relatively inexpensive when compared with human cadavers [9]. However, some studies suggest that the use of non-human model organisms might hinder a student's ability to assimilate and translate knowledge to the human body [10, 11]. On the other hand, using fluid-preserved human cadaveric materials or plastinated human remains (i.e., polymer infusion replacing water and lipids) facilitates the implementation of a regional approach, but these resources are costly and may require special laboratory accommodations. Moreover, a cadaver-based RA might overload students with information because it relies on memorization of numerous anatomical structures when compared with a SBA or problem-based approach [12–14]. Thus, a comparative quantitative analysis of the laboratory curriculum in the undergraduate human anatomy course across institutions will facilitate comparisons in course structure and content. Such information might prove useful to instructors and administrators when redesigning their own course, making curricular modifications, or when seeking to validate course credit transfer among institutions. For example, to develop and incorporate active learning activities in the course, aiming to improve student engagement and retention, it is necessary to have a good understanding of the curriculum. Content organization and delivery directly affect students' engagement with the material [15], and additional activities might overwhelm students, particularly in information-intensive courses. In addition, given the differences among undergraduate human anatomy courses, how can we objectively assess these courses when students are transferring among institutions? Often, such decisions are made based on comparisons of the course syllabi, which provide little information on the teaching materials, resources, and thematic emphases.

Herein, we compare the content of each course and assess the relationship between content and teaching approach (RA or SBA). We attempt to identify and quantify the thematic and structural emphases of each course. To facilitate further comparisons, we also evaluate all curricula against the recommendations of the American Association of Clinical Anatomists [16]. We briefly discuss the challenges and limitations inherent with each teaching approach, as well as in the teaching materials used among the curricula.

Table 1 Summary of the teaching approach, resources, and personnel of the undergraduate human anatomy courses evaluated

School	Approach	Integrated lecture	Cadavers	Prosections	Models	Dissection experience	Animals	Online resources	UTAs	Access to lab (h/week)
KU	Regional	–	+	+	+	–	–	+	+	5.3
JMU	Regional	+	+	+	+	–	–	+	+	3
SWOSU	Systemic	+	–	–	+	+	+	–	+	Open
PSC	Systemic	+	–	–	+	+	+	+	–	2.3

Schools: University of Kansas (KU), James Madison University (JMU), Southwestern Oklahoma State University (SWOSU), and Peru State College (PSC). Use of a particular resource, experience, or personnel is indicated by a plus sign while its absence by a minus sign

UTAs, undergraduate teaching assistants

Methods

Overview of the Courses Evaluated

University of Kansas, Lawrence, Kansas This two-credit-hour laboratory course is separate from the lecture (i.e., has a separate course identifier and grade, and laboratory must be taken after or concurrently with lecture), uses six prosected human cadavers, and follows a RA. The course is divided into the following five content units: (i) introduction, back, and central nervous system; (ii) upper limb; (iii) lower limb; (iv) thorax, abdomen, and pelvis; and (v) head and neck. The nine laboratory sections offered each semester consist of a maximum of 25 students and meet for two 2-h sessions/week. Thus, on average, four students work with each cadaver at any given time. Several prosections and models, as well as a number of multimedia resources served through Blackboard (i.e., pictures of the models used in the laboratory and an online dissection tool) are also available to students to facilitate their learning. Each laboratory section is taught by a graduate teaching assistant (GTA) and four or five undergraduate teaching assistants (UTA). Typically, the GTA gives instructions at the beginning of the class and then students rotate among four or five teaching stations, each facilitated by one or two UTAs. Students spend approximately 20 min/station and generally use the remaining time in the class for review. Throughout the semester, 23 regular laboratory sessions are scheduled, five of them aimed to review the material prior to an exam using a mock exam, so that students become familiar with the format and can determine which material they need to focus on. Additionally, 17 weekend review sessions, each 2 h long and held by one GTA and three or four UTAs, are offered. Thus, each semester students have access to the laboratory an average of 5.3 h/week.

Student learning is assessed during each unit through two quizzes and one exam, both in short-answer format. Quizzes consist of 10 questions each and are worth 14.3% of the course grade, while exams consist of 60 questions each, are timed (2 minutes/question), and are worth 71.4% of the final grade. Prior to each laboratory session students are required to complete an online assignment using the Anatomy and Physiology Revealed 3.0 Program through McGraw-Hill Connect. Each of the 18 online assignments consists of 10 questions and together are worth 12.9% of the course grade; participation in the laboratory accounts for the remaining percentage of the final grade.

Although Grine [17] is followed as a text/laboratory manual, not all structures and topics are covered during the semester due to time constrains. Thus, students are provided with a "structure list" that includes the terms and concepts on each unit they need to know.

Southwestern Oklahoma State University, Weatherford, Oklahoma This four-credit-hour laboratory course is integrated with the lecture, does not use human cadavers, and follows a SBA. The laboratory accounts for 56.9% of the final grade of the course and is divided into six content units as follows: (i) histology and integumentary system; (ii) skeletal system; (iii) nervous system; (iv) muscular system; (v) digestive, respiratory, urinary, and reproductive systems; and (vi) circulatory and lymphatic systems. Each of the seven laboratory sections offered each semester have a maximum enrollment of 20 students and meet for two 2-h sessions/week. This course uses plastic models of human organs, muscles, and bones, as well as fluid-preserved organs from domesticated animals (e.g., sheep's brain and heart). Additionally, starting at the fourth unit (muscular system), students have to dissect fluid-preserved domestic cat specimens obtained from NASCO-Guard Biological Supply Company. A full-time professor teaches each laboratory section with one or two UTAs. In this course, UTAs do not facilitate a single teaching station but move throughout the class working with students individually or in groups. Twenty-two regular laboratory sessions are scheduled, and students have access to the laboratory at all times during the semester.

One quiz and one exam in short-answer format are given per content unit. Quizzes consist of 10 questions each and account for 10% of laboratory final grade; exams consisting of 100 questions each, are not timed, and account for the remaining percentage of the grade. The laboratory session prior to each exam is offered as a review after students take the quiz. A laboratory manual developed by the head instructor of the course (SB) is used as a textbook.

Peru State College, Peru, Nebraska Like Southwestern Oklahoma State University (SWOSU), this is a four-credit-hour course with the laboratory (one credit hour) integrated with the lecture. Human cadavers are not used, and the material is presented within a SBA. The laboratory accounts for 27.2% of the course grade and is divided into three units: (i) histology and skeletal system; (ii) muscular system; and (iii) circulatory, digestive, respiratory, urinary, and reproductive systems. Eleven 2-h laboratory sections are offered each semester with a maximum enrollment of 24 students each. Laboratory material consists of plastic models of human organs and bones and fluid-preserved cat dissections. Cats are obtained from Bio Corporation, Alexandria, Minnesota. A full-time professor teaches each laboratory section. Teaching assistants are not available. The laboratory is not available outside of the 2-h allotted period with the exception of a 1-h review session held before each of the three laboratory practical exams. Some models are available for access and study through the library. Three laboratory exams are administered throughout the semester, one for each unit. Each practical exam is worth 50 points and has 50 questions. The questions are identification questions based on the key terms found in weekly laboratory handouts. Each laboratory exam is timed so that students spend approximately 2 min at each station consisting of three to five questions. The students rotate through roughly 12–14 stations. Additional 10–15 min are granted after the rotation is completed to re-examine any structures that the student may have questions on.

The remainder of the course work is based on four homework (18.2%) exercises and three in-class lecture exams (54.6%). Homework assignments primarily consist of questions from lecture material but often significantly overlap laboratory structures. These homework assignments are largely computer based. The laboratory manual was developed by one of the professors.

James Madison University, Harrisonburg, Virginia This four-credit-hour course involves 2.5 h of lecture that is run synchronously with 3 h of laboratory each week using a RA. Two lecture sections (240–310 students each) and eighteen laboratory sections (maximum of 40 students each) are offered each semester. Laboratory uses multiple prosected human cadaver plastinates (full-body and regional specimens), plastic models, wall charts, and interactive digital displays. The course is divided into the following units: (i) introduction, trunk musculoskeletal systems, nervous system (spinal cord), and thorax; (ii) abdomen, pelvis, and perineum; (iii) lower limb; (iv) upper limb; and (v) head and neck. Each laboratory section is taught by a faculty member (Ph.D., MD, or equivalent) and one or two UTAs. Typically, the faculty member gives a very brief introduction or quiz at the beginning of the class and then students are free to examine materials throughout the laboratory. Throughout the semester, 25 regular laboratory sessions are scheduled; no laboratory sessions are specifically allotted to review. Thus, each semester, student's access to the laboratory is limited to 3 h/week.

Students' learning is assessed through quizzes and exams. Because the laboratory and lecture are connected, grades from both are combined to calculate an overall course grade. For the lecture portion of the course, exams (four) are worth 50% of the total grade, with the final exam (cumulative) representing 20% of this amount. Lecture exams are generally multiple-choice format. Five laboratory exams (40–50 questions each) comprise 45% of the course grade, are not timed, and are not cumulative. Quizzes consist of ten questions each and are worth 5% of the course grade.

A course-specific laboratory manual [18] is followed as a textbook in addition to an atlas of human anatomy, which are the only required materials for the course. The laboratory manual highlights all required structures and provides brief descriptions and explanations that allow students to understand the context and relevance of the structures. Lecture faculty may require or recommend additional materials (e.g., course note packs, text book, supplementary study material). Electronic resources (practice quizzes, links to anatomical materials, and supplemental readings and images) are available through James Madison University (JMU) Canvas. On average, 2 to 4 h/week of peer-assisted supplemental learning (PASS = tutoring) sessions are available to students outside of regular class time. Peer educators from the James Madison University Learning center work collaboratively with the Anatomy lecture faculty to facilitate these sessions.

Curriculum Quantification

To evaluate the structure of the laboratory curriculum of each course, we used the list of structures provided to the students at University of Kansas (KU), SWOSU, JMU, and Peru State College (PSC), either in laboratory manuals or as structure lists. We counted and classified all terms listed in these documents within the following categories: structures, concepts, and clinical applications. We defined structures as those terms related to gross anatomical features that students are primarily required to identify during an exam because they are visually recognizable (e.g., deltoid tuberosity of the humerus, phrenic nerve, etc.). We considered concepts to be those terms that students are required to provide an explanation for, and not necessarily to visually identify (e.g., functions, origins and insertions of muscles, blood flow through the heart, etc.). We considered clinical applications any information related to clinical aspects, such as injuries, diseases, or medical conditions (e.g., shoulder separation, carpal tunnel syndrome, sciatica, etc.). When students are required to identify separately two or more structures within the same organ, we counted them separately. For example, we counted as two separate structures the two heads of biceps brachii. Conversely, when students are required to identify more than one structure under a single term (e.g., venae comitantes), we counted them only once. In addition, we quantified the proportion of bone markings per bone, and the proportions of functions and innervations, and origins and insertions per muscle because they varied between courses.

To facilitate further comparisons, we assessed the content distribution of each curriculum following the topographic anatomy approach proposed by Grković et al. [19], in which anatomical terms are divided into the following eight major modules: (i) introduction, (ii) thorax, (iii) abdomen, (iv) pelvis and perineum, (v) upper limb, (vi) lower limb, (vii) head and neck, and (viii) back. We counted all terms and grouped them within these categories, expressing them as the percentage of the total number of terms. Then, we compared the content distribution of all courses with that of the American Association of Clinical Anatomists (AACA) recommendations [16], which was calculated by Grković et al. [9]. When a term could be included in more than one module, we followed the regional divisions of the human body proposed by Drake et al. [20]. For example, the os coxae could be counted as part either of the pelvis and perineum module or within the lower limb; according to Drake et al. [20], we included them within the lower limb.

Statistical Analyses

We used a Chi-square test to compare: (i) the distribution of total number of terms, structures, and concepts among the curricula, among the content units within each curriculum, and between teaching approaches; (ii) the number of blood vessels, bones, muscles, and nerves among curricula and between teaching approaches; and (iii) the distribution of the proportion of terms within each anatomical module of the evaluated curricula and the AACA recommendations. Because data were not normally distributed, we used a Kruskal-Wallis test to compare the average number of terms, structures, and concepts per laboratory session and proportion of bone markings per bone among curricula. We used a Mann-Whitney test to compare the total number of terms, structures, concepts, blood vessels, muscles, and nerves between teaching approaches. We used post hoc Mann-Whitney tests with Bonferroni correction to assess significant differences in the average number of terms, structures and concepts per laboratory session between pairs of curricula. We considered a P value of < 0.05 to be statistically significant.

Results

Comparisons Among Curricula The total number of terms was significantly different among curricula, Chi-square test χ^2 (3, $n = 4850) = 551.99$, $P < 0.05$, with that of KU having the highest and PSC the lowest numbers (Fig. 1a; Tables 2 and 3); the total number of terms at JMU and SWOSU were not significantly different from each other, χ^2 (1, $n = 2440) = 2.62$, $P = 0.105$. In the SWOSU curriculum, about 34% of the total number of terms correspond to structures or concepts related to anatomical features of the domestic cat and sheep; this value was 21% for PSC, which only uses cats.

In all curricula, the majority of terms corresponded to the structures category followed by concepts; terms referring to clinical applications accounted for less than 1.3% of the total number of terms in all curricula, except for that of SWOSU where no clinical applications are included (Fig. 1b). Of the total number of terms per curriculum, SWOSU has the highest percentage of structures (87.5%) and the lowest of concepts (12.5%) whereas JMU the lowest percentage of structures (65.2%) and the highest of concepts (33.5%). The total number of structures and concepts per laboratory session was significantly different among curricula (Tables 2 and 3; structures: $H(3) = 14.19$, $P < 0.05$; concepts: $H(3) = 14.78$, $P < 0.05$). A post hoc test using Mann-Whitney tests with Bonferroni correction showed significant differences only between KU and JMU in the number of structures and between KU and SWOSU and between KU and PSC in the number of concepts ($P < 0.01$).

Within each curriculum, the distribution of the total number of terms among content units were significantly different (KU: χ^2 (4, $n = 1818) = 42.1$, $P < 0.05$; JMU: (4, $n = 1260) = 164.58$, $P < 0.05$; SWOSU: (5, $n = 1180) = 63.0$, $P < 0.05$; PSC: (2, $n = 628) = 7.89$, $P = 0.02$); thus, some content units had a significantly higher number of terms than others (Fig. 1c; Tables 2 and 3). Likewise, within each curriculum, the number of terms per laboratory session varied greatly (Fig. 1d) and there were significant differences among curricula (Kruskal-Wallis test $H(3) = 18.41$, $P < 0.05$). For example, one laboratory session at SWOSU contained only 15 terms while one at KU contained as many as 194. Although both the average number of terms per laboratory session and standard deviation were highest for KU ($\bar{x} = 101 \pm 40.9$, 47–194, $n = 18$), almost doubling the values obtained for the other curricula (JMU: $\bar{x} = 52.5 \pm 28.8$, 22–127, $n = 24$; SWOSU: $\bar{x} = 53.4 \pm 26.6$, 15–103, $n = 22$; PSC: $\bar{x} = 62.8 \pm 29.3$, 15–103, $n = 10$), the standard deviations were not significantly different ($P = 0.48$) and a post hoc test using Mann-Whitney tests with Bonferroni correction only showed significant differences in the average number of terms per laboratory session between KU and JMU and between KU and SWOSU ($P < 0.01$).

The total number of blood vessels, muscles, bones, and nerves was significantly different among curricula, blood vessels: χ^2 (3, $n = 457) = 67.74$, $P < 0.05$; muscles: (3, $n = 583) = 74.42$, $P < 0.05$; bones: (3, $n = 179) = 35.4$, $P < 0.05$; nerves: (3, $n = 109) = 64.25$, $P < 0.05$. The highest numbers of blood vessels, human muscles, and bones were recorded for KU whereas the lowest for blood vessels and muscles was at PSC, and the lowest for bones was SWOSU (Table 4). The highest number of nerves was recorded for JMU; no nerves are included in PSC's curriculum. In SWOSU's curriculum, 75.6% of the number of blood vessels and 50% of the muscles are studied from the cat. These values were lower in PSC (27.1 and 31.9% for blood vessels and muscles). The proportion of bone markings per bone was not significantly different among curricula, $H(3) = 6.01$, $P = 0.11$; the highest value was recorded from SWOSU (5.6 markings per bone), the lowest for JMU (2.5). Functions, innervations, origins, and insertions of muscles are only part of the curriculum of KU and JMU and not required for PSC and SWOSU.

Comparison Between Regional and System-Based Approaches When we pooled the data by the type of teaching method, the RA has a significantly higher total number of terms (χ^2 (1, $n = 4850) = 313.97$, $P < 0.05$), structures ((1, $n = 3593) = 115.79$, $P < 0.05$), and concepts ((1, $n = 1258) = 280.47$, $P < 0.05$) than a SBA. However, the total number of terms, structures, and concepts per laboratory

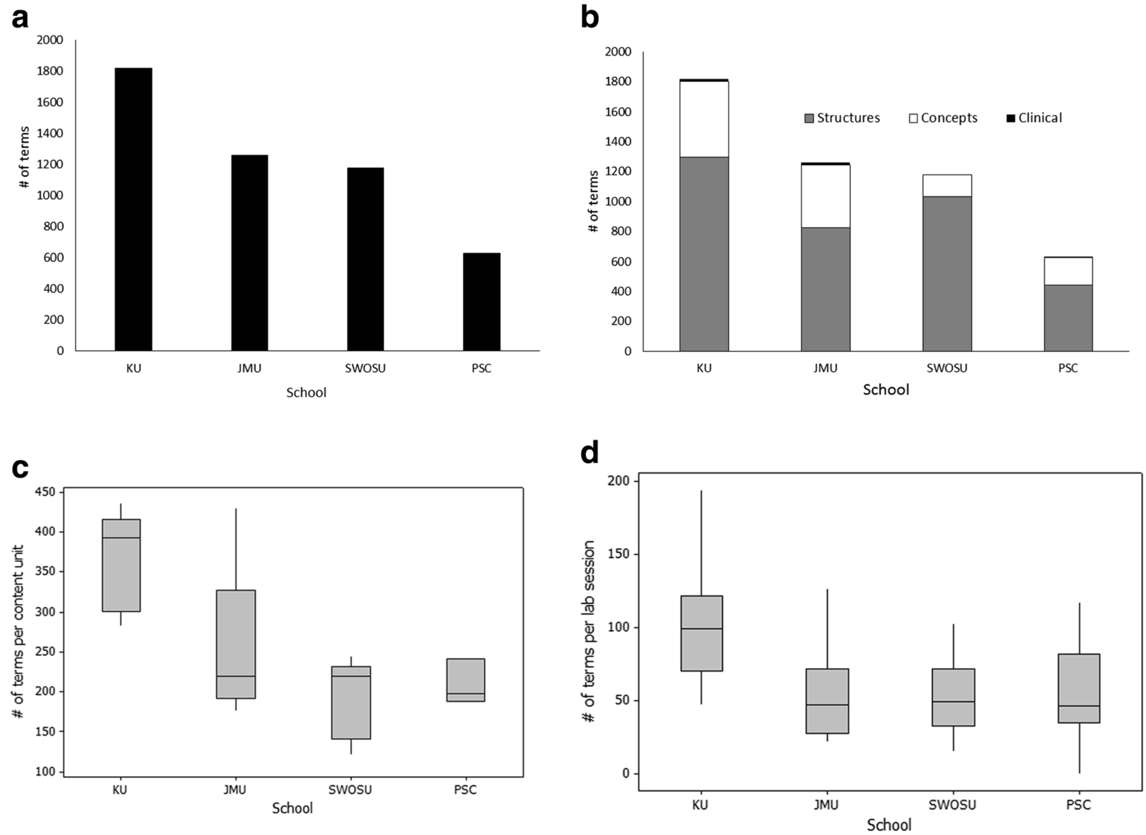

Fig. 1 Comparison of the laboratory curricula of the University of Kansas (KU), James Madison University (JMU), Southwestern Oklahoma State University (SWOSU), and Peru State College (PSC). **a** Total number of terms; **b** terms divided in structures, concepts, and clinical applications (see text for explanation); **c** number of terms per content unit; **d** number of terms per lab session. Boxplots display median and quartiles

Table 2 Comparison of the laboratory curriculum between the University of Kansas (KU) and James Madison University (JMU), institutions with courses that follow a regional approach

KU							JMU					
Content unit	L	St	Co	Cl	To	Tu	L	Sr	Co	Cl	Ta	Tu
I	3	56.0 ± 6.2 (51–63, *n* = 168)	38.3 ± 23.8 (17–64, *n* = 115)	–	94.3 ± 20.6 (80–118)	283	6	29.3 ± 9.6 (18–46, *n* = 176)	5.2 ± 10.3 (0–26, *n* = 31)	0.3 ± 0.5 (0–1, *n* = 2)	34.8 ± 9.1 (25–47)	209
II	4	56.5 ± 39.6 (17–101, *n* = 226)	22.0 ± 13.8 (5–36, *n* = 88)	1.3 ± 1.9 (0–4, *n* = 5)	79.8 ± 37.9 (47–115)	319	3	53.0 ± 20.0 (40–76, *n* = 159)	4.7 ± 5.0 (0–10, *n* = 14)	1.0 ± 1.7 (0–3, *n* = 3)	58.7 ± 26.5 (40–89)	176
III	3	104.0 ± 30.2 (76–136, *n* = 312)	38.0 ± 23.1 (12–56, *n* = 114)	3.7 ± 2.9 (2–7, *n* = 11)	145.7 ± 18.8 (124–158)	437	4	22.5 ± 8.6 (12–33, *n* = 90)	33.0 ± 40.8 (0–84, *n* = 132)	0.5 ± 1.0 (0–2, *n* = 2)	56.0 ± 37.5 (22–10-7)	224
IV	4	82.8 ± 26.1 (45–103, *n* = 331)	16.0 ± 11.1 (2–29, *n* = 64)	0.3 ± 0.5 (0–1, *n* = 1)	99.0 ± 21.8 (74–121)	396	4	29.8 ± 12.4 (22–48, *n* = 119)	25.0 ± 50.0 (0–100, *n* = 100)	0.3 ± 0.5 (0–1, *n* = 1)	55.0 ± 49.7 (22–12-7)	220
V	4	65.0 ± 49.4 (29–138, *n* = 260)	30.8 ± 21.3 (4–56, *n* = 123)	–	95.8 ± 66.1 (54–194)	383	7	39.7 ± 25.4 (13–76, *n* = 278)	20.7 ± 20.7 (0–55, *n* = 145)	1.1 ± 1.2 (0–3, *n* = 8)	61.6 ± 22.2 (23–90)	431
Total	18	1297	504	17		1818	24	822	422	16		1260

The average is given followed by the standard deviation with ranges and total number of terms in parentheses

Abbreviations: *L*, number of laboratory sessions within a particular content unit; *St*, number of terms classified as structures; *Co*, number of terms classified as concepts; *Cl*, number of terms classified as clinical applications; *To*, average of the total number of terms (i.e., sum of structures, concepts, and clinical applications) per lab session within a particular content unit; *Tu*, total number of terms per content unit

Table 3 Comparison of the laboratory curriculum between Southwestern Oklahoma State University (SWOSU) and Peru State College (PSC), institutions with courses that follow a systemic approach

SWOSU							PSC					
Content unit	L	St	Co	Cl	To	Tu	L	St	Co	Cl	To	Tu
I	4	14.8 ± 10.1 (5–27, *n* = 59)	15.8 ± 6.3 (7–22, *n* = 63)	–	30.5 ± 115.1 (15–49)	122	5	45.5 ± 37.2 (14–89, *n* = 182)	15.0 ± 10.7 (5–30, *n* = 60)	–	60.5 ± 31.2 (25–94)	242
II	3	75.0 ± 26.1 (45–92, *n* = 225)	6.7 ± 3.1 (4–10, *n* = 20)	–	81.7 ± 23.3 (55–98)	245	3	26.7 ± 26.7 (2–55, *n* = 80)	38.7 ± 19.1 (23–60, *n* = 116)	0.7 ± 1.2 (0–2, *n* = 2)	66.0 ± 44.5 (35–117)	198
III	3	62.3 ± 3.8 (58–65, *n* = 187)	13.3 ± 13.6 (5–29, *n* = 40)	–	75.7 ± 9.8 (70–87)	227	3	60.0 ± 19.0 (41–79, *n* = 180)	2.7 ± 0.6 (2–3, *n* = 8)	–	62.7 ± 19.5 (43–82)	188
IV	5	43.0 ± 21.3 (21–77, *n* = 215)	1.8 ± 1.6 (0–4, *n* = 9)	–	44.8 ± 20.6 (24–78)	224						
V	3	67.7 ± 25.7 (49–97, *n* = 203)	4.0 ± 2.7 (1–6, *n* = 12)	–	71.7 ± 27.8 (50–103)	215						
VI	4	35.8 ± 19.5 (18–61, *n* = 143)	1.0 ± 0.8 (0–2, *n* = 4)	–	36.8 ± 19.8 (19–62)	147						
Total	22	1032	148	0		1180	11	442	184	2		628

The average is given followed by the standard deviation with ranges and total number of terms in parentheses

Abbreviations: *L*, number of laboratory sessions within a particular content unit; *St*, number of terms classified as structures; *Co*, number of terms classified as concepts; *Cl*, number of terms classified as clinical applications; *To*, average of the total number of terms (i.e., sum of structures, concepts, and clinical applications) per lab session within a particular content unit; *Tu*, total number of terms per content unit

session was not significantly different between approaches (Mann-Whitney test, total terms: $U = 1715.5$, $P = 0.127$; structures: $U = 1639$, $P = 0.65$; concepts: $U = 1728$, $P = 0.16$). The total number of blood vessels, bones, and nerves was significantly higher in the RA than in the SBA (blood vessels, χ^2 (1, $n = 457$) = 29.95, $P < 0.05$; bones: χ^2 (1, $n = 179$) = 33.12, $P < 0.05$; nerves: χ^2 (1, $n = 109$) = 60.19, $P < 0.05$). If only human muscles are considered, the RA also has a higher number of muscles, χ^2 (1, $n = 455$) = 48.79, $P < 0.05$. Such a difference is not significant when the number of muscles from the cat are included, χ^2 (1, $n = 583$) = 0.76, $P = 0.38$. The proportion of bone markings per bone was not significantly different between approaches, $U = 104$, $P = 0.06$.

Comparison with AACA Recommendation The proportion of terms devoted to each of the eight anatomical modules in the curriculum of all courses was significantly different ($P < 0.05$) from each other (Table 5; Fig. 2) as well as from that of AACA recommendation, KU: χ^2 (7, $n = 1782$) = 760.36, $P < 0.05$; JMU: (7, $n = 1260$) = 324.09, $P < 0.05$; SWOSU: (7, $n = 1180$) = 91.5, $P < 0.05$; PSC: (7, $n = 628$) = 336.24, $P < 0.05$. The proportion of terms of each anatomical

Table 4 Total number and average of the proportion of terms associated with some structures covered in the laboratory curricula of the University of Kansas (KU), James Madison University (JMU), Southwestern Oklahoma State University (SWOSU), and Peru State College (PSC)

Structure	KU	JMU	SWOSU[a]	PSC[a]
Arteries/veins	182	105	111 (84)	59 (16)
Muscles	167	135	212 (106)	69 (22)
Bones	71	57	24	27
Markings per bone	3.3 ± 1.6, 1.5–6.0	2.5 ± 1.2, 0.7–4.0	5.6 ± 1.2, 4.4–6.8	3.3 ± 1.6, 2.1–4.5
Nerves	45	50	14	0

For bone markings, the average is followed by the standard deviation and range

[a] The total number of blood vessels and muscles from human and cat is followed by that of the cat in parentheses

Table 5 Comparison of the number of terms within each topographical region of the body among the recommendation of the American Association of Clinical Anatomists (AACA) and the curricula of the University of Kansas (KU), James Madison University (JMU), Southwestern Oklahoma State University (SWOSU), and Peru State College (PSC)

Module	AACA	KU	JMU	SWOSU	PSC
Introduction	131 (5.5)	61 (3.4)	25 (2.0)	122 (10.3)	113 (18.0)
Thorax	331 (13.9)	174 (9.8)	71 (5.6)	145 (12.3)	72 (11.5)
Abdomen	280 (11.7)	157 (8.8)	66 (5.2)	93 (7.9)	81 (12.9)
Pelvis and perineum	248 (10.4)	65 (3.7)	121 (9.6)	105 (8.9)	31 (4.9)
Upper limb	251 (10.5)	335 (17.9)	220 (17.5)	117 (9.9)	112 (17.8)
Lower limb	240 (10.1)	445 (24.5)	250 (19.8)	160 (13.6)	106 (16.9)
Head and neck	817 (34.3)	431 (23.5)	439 (34.8)	380 (32.2)	88 (14.0)
Back	87 (3.6)	150 (8.4)	68 (5.4)	58 (4.9)	25 (4.0)
Total	2385	1818	1260	1180	628

Values corresponding to the AACA recommendations are from Grković et al. [19]. Percentages (in parentheses) may not add up to 100 in each column due to rounding

module was significantly different between both curricula with a regional approach (KU-JMU (7, $n = 1260) = 264.23$, $P < 0.05$) as well as between those with a systemic approach (SWOSU-PSC (7, $n = 628) = 177.54$, $P < 0.05$). The curriculum in both courses using a SBA has a higher proportion of terms in the Introduction module than those using a RA. The curriculum of all courses have a higher proportion of terms in the upper- and lower-limb modules than that of the AACA, except for the upper-limb module of PSC, which was similar to that recommended. However, in the curriculum of all courses except for that of PSC, the module head and neck has a higher proportion of terms and thus somewhat follows the AACA recommendation.

Discussion

Our quantitative analysis showed significant differences among curricula in the total number of terms, as well as in the number of terms categorized as structures and concepts included in each curriculum. We expected such results considering the differences in the approach, teaching materials, resources, and teaching personnel among institutions. In the absence of human cadavers and limited resources, some courses choose to utilize plastic models and non-human dissection materials (e.g., cats). Teaching assistants are not available for all programs, although there are clear benefits of peer-mediated learning [21]. The differences in the total number of terms among content units of each curriculum reflect the nature of the course, as some body regions (e.g., head and neck) and body systems (e.g., skeletal system, nervous system) contain more structures than others. Thus, it is almost inevitable that some content units and laboratory sessions have more terms and are more time demanding for students than others. Despite differences, a similarity among curricula was that the majority of terms referred to structures, which reflects the main goal of all courses analyzed (i.e., identification and recognition of gross anatomical structures). Another similarity was the low percentage of clinical applications, which help students to apply their knowledge [22]. This category

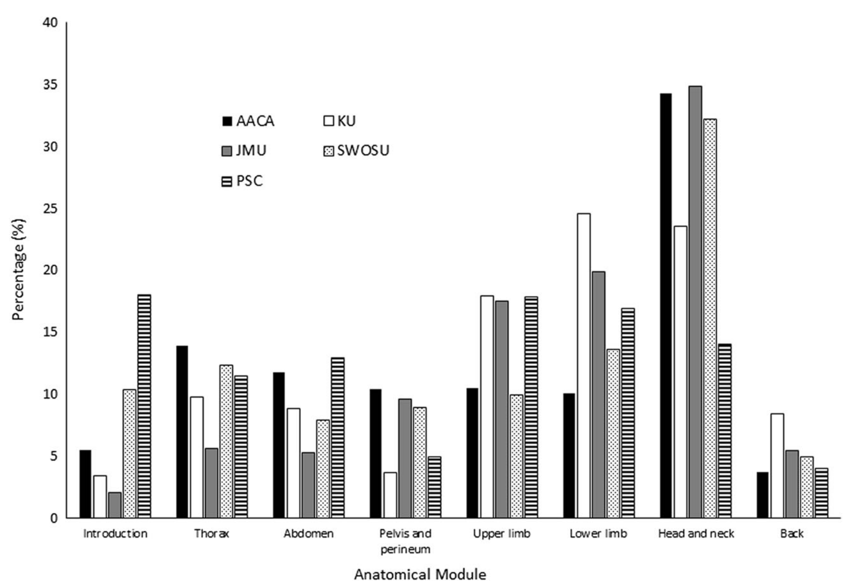

Fig. 2 Comparison of the proportion of terms within each topographical region of the body among recommendations of the American Association of Clinical Anatomists (AACA; $n = 2385$) and the laboratory curricula of the University of Kansas (KU; $n = 1782$), James Madison University (JMU; $n = 1260$), Southwestern Oklahoma State University (SWOSU; $n = 1180$), and Peru State College (PSC; $n = 628$). Values corresponding to the AACA recommendations taken from Grković et al. [19]

accounted for less than 1.3% of the total number of terms for all curricula except for that of SWOSU, which did not contain any clinical applications. Terms related to clinical applications include osteoporosis, spasmodic torticollis, aneurysm, and shoulder separation and dislocation. We expected these findings given that the courses evaluated are introductory courses and pre-professional students will get clinical anatomy in graduate school. This does not mean that clinical applications are completely ignored in these courses, because structures can be incorporated into application questions without teaching the clinical terminology. In addition, clinical applications are sometimes incorporated in the lecture course, which was not evaluated here. Therefore, the assessment of the latter curriculum is necessary if we want to design and incorporate selected clinical applications into the laboratory that help students to reinforce or contextualized the material covered in lecture.

When comparing the regional and system-based courses, the total number of terms, concepts, and structures was significantly higher in a RA than a SBA (Fig. 1a; Tables 2 and 3). At first glance, it may appear as though a RA is more comprehensive and thus preferential to a SBA due to the high number of terms. However, our analysis only provides information on the learning quantity, not the quality of each approach. In addition, it does not discriminate among the learning value of the quantified terms. Furthermore, a greater number of terms is not always better, and the content of a RA may overwhelm students with information leaving less room for application of knowledge or adoption of innovative peer-mediated or discovery-based activities that may foster critical thinking [12]. For example, in the Spring of 2015, we incorporated a brief group activity involving the self-identification and quantification of prevalence/absence of Palmaris longus during a regular anatomy laboratory session at KU (a RA course). Based on post-participation surveys, students perceived negatively the time spent in this additional activity because they felt there was not enough time to cover the regular course material. The opposite case seemed to have occurred when the same activity was administered to the students at SWOSU (a SBA course) in the Spring of 2014 (VHG, personal observation). Students at KU are required to learn 35% more terms than students at SWOSU (Fig. 1a–d), and such a difference might have accounted for the opposite reactions of this experience.

One major difference between the courses in this study are the laboratory resources available for teaching. Both KU and JMU use human cadavers in a RA course whereas PSC and SWOSU (SBA courses) both use cats and non-human animal organs for dissection. Although the domestic cat exhibits a body plan anatomically similar to that of a human and has been used as a model organism in human anatomy courses, there are still major differences that may prevent students from assimilating and applying their knowledge to humans. For example, some studies show that students learning human anatomy from clay human models earned higher exam scores compared with students performing cat dissections [10, 11]. Although studying human anatomy from cats or any non-human model may not be ideal, it is perhaps the best option in the absence of human cadavers or body organs. In addition, the hands-on learning experience provided during the dissection of these animals and organs are extremely valuable for students in both undergraduate and medical school anatomy courses. For example, Kivell et al. [23] reported a high level of satisfaction from students and faculty when medical students dissected a pig's eye during their ophthalmology rotation instead of human eyes, which are limited.

The two courses using a regional approach to anatomy (JMU and KU) utilize cadaveric material. Human cadavers provide a unique resource that is not widely offered to undergraduates. A key difference, however, is that KU uses wet (fluid preserved) cadavers and JMU uses plastinated cadavers. Although both forms of cadavers are valuable to the anatomy students, wet specimens offer the learner the ability to kinesthetically engage with the body and provide a more realistic learning experience with respect to the morphology of various organs [24]. Plastinated cadavers offer the benefits of having professional quality of dissection and long-life expectancy, but parts are rigid and immobile. Students working with the dry plastinates miss out on kinesthetic experiences, such as moving organs within the abdomen or being able to palpate the differences between an artery, vein, and nerve.

The proportion of terms within each module in all curricula was significantly different from each other and from the AACA recommendations (Fig. 2; Table 5). The two RA courses were significantly different with respect to the distribution of terms among modules. The two SBA courses were also significantly different from each other. All four curricula had a greater proportion of terms in the upper-limb and lower-limb modules than recommended by the AACA, with the exception of the upper-limb module of PSC, which was similar to the recommendations (Table 5). This comparison may prove valuable when modifying the structure of these courses. Visualizing which areas are overloaded with terms allows faculty to reorganize the curricula to better coincide with the AACA recommendations. For example, because the lower-limb module for KU contains much more information than the AACA recommends, it may be beneficial to reduce the number of terms required for this unit. One possibility would be to no longer require the students to memorize all of the origins and insertions for the intrinsic muscles of the feet. Instead, those terms could be focused elsewhere, such as the pelvis and perineum. This comparison may also be useful for determining the day-to-day schedule of the laboratories. Instructors can use the AACA recommendations to minimize any discrepancies between lengths of individual laboratory sessions.

Implications of the Study

As instructors and students of anatomy, we anticipate that the results of this study will facilitate curricular assessment and redesign. As a framework for evaluating current curricula, we recommend quantifying course materials to determine the proportion of content in each unit. This may elucidate segments of the course that are overloaded with information and those that might benefit from the incorporation of additional materials or classroom learning strategies. This analysis may also prove useful when determining course equivalency for transferred credits.

This study elucidates differences among programs with regard to teaching strategies and approaches. For example, peer teaching has emerged as a valuable and worthwhile approach for undergraduate anatomy by either incorporating UTAs into the course or implementing supplemental instruction outside the classroom. Three of the four anatomy courses evaluated in this study utilize UTAs, but only at JMU and KU are they involved in the actual teaching of course material. Both students and peer teacher benefit from the experience [25]. Likewise, the findings of Bruno et al. [26] suggesting that supplemental instruction in an anatomy course might increase students' performance in the course have been observed by some of us directly in our own courses (DSM and VHG).

Another strategy we recommend for undergraduate anatomy courses is the regular use of radiographic images and sectional anatomy (models or cadaveric prosections) to promote the application of knowledge. JMU utilizes sectional anatomy (models, images, and plastinated prosections) materials to challenge students to apply their knowledge of structures from one anatomical plane to another. Sectional materials require that students know structures in context and be able to recognize them in multiple views, which is relevant to and forms the foundation necessary for understanding and interpreting other forms of clinical and diagnostic imaging techniques. Some laboratory sessions in all four courses analyzed include the use of medical imaging (though to varying degrees). Radiographic and other forms of medical images require students to recall anatomical information in an abstract setting and may allow for clinical applications leading to higher levels of learning, especially when viewing radiographs of both "normal" anatomy and those with pathological abnormalities [25].

Finally, with the current generation of tech-savvy millennials, it is no surprise that students may be generally receptive of the idea of using online study resources [27]. Students may benefit from the flexibility of completing online assignments on their own time, in a setting in which they are most comfortable. Though it may be tempting to utilize the technological skills of generation Y students, it is important to be mindful that some laboratory experiences cannot be replicated in an online setting. Some studies have shown that the human cadaver laboratory provides a significant advantage over multimedia resources [28, 29]. KU uses Blackboard for practice quizzes, pictures, and videos of the plastic models used in laboratory. KU also has an optional dissection tool to help students review cadaveric material. Similar to KU, JMU uses Canvas for providing practice quizzes, supplemental materials, and image resources. PSC has online homework, primarily aimed at the lecture, but it overlaps with the laboratory and has optional online dissection tools available. In addition to benefiting from the use of online resources, students may also benefit from the implementation of formative assessments [30]. PSC includes formative assessments in its anatomy curriculum by way of in-class activities. The laboratory manual created by the professor is unique, in that it requires student-directed dissections and identification of structures. KU and JMU both provide both graded quizzes and mock exams (ungraded learner-focused activities) as formative assessment that can assist students in being active learners as opposed to passive learners.

Limitations of the Study

The main limitation of this study was sample size. We compared only four undergraduate anatomy courses and thus, our results do not represent all possible approaches used in other institutions. However, available information indicates that similar approaches are commonly implemented [6–8]. In addition, we did not take into account the effect of having laboratory courses integrated with a corresponding lecture component. In our study, only KU does not have a close association between lecture and laboratory. This is an artifact of laboratory space limitations, thus students in lecture may or may not be in the laboratory concurrently. In those courses with corresponding lectures and laboratory sections, some terms, concepts, and clinical applications may be provided in the lecture component as additional materials, not included in the laboratory manuals and structure lists we used to quantify these courses. Further studies should also assess the content of the lecture component.

Additionally, we did not discriminate among the types of structures and concepts quantified. Our categorization and numerical analysis assumes that all structures have the same learning value, which as instructors we know it is not true. For undergraduate students, learning some anatomical structures might be more important because of their clinical significance (e.g., knee ligaments) or because they will facilitate learning other anatomically related information in more advanced courses (e.g., major body muscles and vessels). A similar case occurs for the terms grouped as concepts, which ranged from origins of muscles to the different types of epithelial tissues. Undoubtedly, each concept carries a different level of significance and learning value.

Finally, our study did not assess the presence or absence of critical content components nor the learning objectives of each content unit. Thus, it does not evaluate the quality of the curriculum. However, such an assessment is out of the scope of this work, and further studies should try to incorporate it in their analyses.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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