American International Journal of Biology
July-December 2014, Vol. 2, No. 3 & 4, pp. 01-23
ISSN: 2334-2323 (Print), 2334-2331 (Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/aijb.v2n3-4a1
URL: http://dx.doi.org/10.15640/aijb.v2n3-4a1

Region vs. System-Based Anatomy: Efficacy and Implementation

Orhan E. Arslan[1]

Abstract

Most basic medical science disciplines follow a system-based teaching module, including components of anatomy, such as microscopic and developmental anatomy.Gross anatomy's transformation from a region-based to a system-based module is a natural transition that enables the building of a cohesive and integrated curricular experience and demonstrably enhances understanding of other basic science and clinical courses. This study is designed to address the efficacy and practicality of the system-based anatomy teaching module implemented at the University of South Florida/Morsani College of Medicine since 2006.As such, the overall impacts of this curricular change on student performance in anatomy, USMLEPart1 and part II, and on course rating were examined. It utilizes the concepts of spaced repetition and peer-to-peer teaching, enhancingleadership capabilities, and solidifying vertical and horizontal integration. To maximize its efficacy, this module was reinforced by the introduction of ultrasound-based, procedure-based and radiography-based anatomy teaching.We have demonstrated that a system-based anatomy is an efficient, dynamic teaching curriculum that offers asuccessful avenue for long-term retention, decreaseslearners'workload, strengthens understanding of the anatomical basis of disease processes, fosters the skills necessary to perform surgical procedures, and improves learners' performance in both university and national exams.

Keywords: system-based, region-based, curriculum, spaced-repetition, spaced-stratified

1. Introduction

Since the Institute of Medicine published its recommendations for medical education reform in 2003 [1] many U.S. medical schools have launched extensive curriculum overhaul efforts.

[1]DVM, PhD, Department of Pathology and Cell Biology, University of South Florida Morsani College of Medicine, 12901 Bruce B. Downs Blvd., MDC Box 11, Tampa, FL 33612.
Email: oarslan@health.usf.edu, Phone: (813) 974-0636

The curricula have been remodeled to include courses in evidence-based clinical reasoning, patient-centered care, professionalism, and healthcare system.Along with these changes, several ideas were proposed as well as some forms of system-based curricula[2, 3, 4, 5].In this paradigm, students learn the molecular biology, biochemistry, structure, and function of the body one system at a time.

The system-based anatomy is designed to provide the learner with the opportunity to develop a foundation in one system as a prelude to the system that follows within a spaced-stratified learning module.By the end of the academic year, the relationships, functional significance and clinical correlations of structures that belong to different systems are discussed, dissected andconsecutively revisited several times. In other words, when the structures that pertain to the musculoskeletal system are covered and the learner proceeds to the study of the nervous system, the knowledge attained relative to the skin, ligaments, tendons, and muscles and their functions will be revisited within the context of innervation and relationships as well as the ensuing sensory and motor dysfunctions.As the learner moves further forward, anatomic structures discussed within the musculoskeletal and nervous systems are reintroduced in conjunction with subsequent systems, the cardiovascular, respiratory, digestive, reproductive, and urinary systems.Thus, this curricular model promotes and fosters, in continuum, an academic yearin which educational reinforcement and integration are supplemented at each stage with procedure-and imaging-based modules and comprehensive assessment methodologies.In this manner and through the duration of the course and academic year, a successive and reinforced multilayer knowledge, repeated at varying intervals, is attained and a broad picture of the entire anatomy emerges.As the learner concludes the study of anatomy, he/she has revisitedwith intervening spaces all the functional systems of the human body. This is supported by research data that indicate that repetition of reading material at intervals exerts facilitatory effect by reducing the summed fixation time, number of ocular fixations and increases length of saccades[6]. This fact correlates with the findings that word-toward semantic repetitioncauses a decrease in the activity of the left inferior prefrontal gyrus [7].

The concept of “spaced repetition,”which encompasses partitioning of a subject matter into interdependent units taught at intervals, and is subsequently repeated and tested after variable intervals, has shown promising effects with regard to learning and retaining the fundamental knowledge of the subject matter [7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21].

Repetition with comprehensive assessment methodologies at various stages of the study of the material previously covered helps to solidify encoded information and thus strengthen retention and improve performance [22, 23, 24].Improvement of learner's retention creates a greater satisfaction with the educational model and enhancesthe positive learning environment [4, 5, 25, 26, 27] paving the way for the expansion of this module of teaching to other aspects of medical education.

The role of dissection in anatomy teaching has been the subject of considerable recent debate [24, 28, 29, 25, 31,32, 33, 34].We continue to favor its use, as students gain competency in kinetic skills, comparison of 2D and 3D structural relationships, and overall appreciation of the human body as well as cognition of life and death issues. A system-based teaching module allows more efficient utilization of cadaveric resources than that of the traditional regional approach. As such, the utilization of a system-based approach pairs comfortably with dissection-led anatomic study [4].

In our model, learners use one half of the donor (cadaver) body to thoroughly dissect the peripheral nerves when studying the structural organization of the nervous system while utilizing the other half of the body to perform a detailed dissection of the arteries and veins within the cardiovascular course. The learner concludes his/her assignments withthe dissection of the visceral organs while revisiting their innervation, vasculature, and lymphatic drainage, which are discussed within the previous systems.Through this approach, structures associated with the entire body are bilaterally dissected andfully examined.Thus, the ability of the learner to master material and structures with one system as a foundation to the subsequent systems will be much greater than that of a learner who pursues a region-based approach, which primarily provides a one-time exposure to functionally unrelated structures I an entire academic year.

Due to the easy accessibility and relatively large size of the structures involved the musculoskeletal system is the first system taught and dissected in this model. The initial work performed by the learner to reflect the skin and dissect the muscles, ligaments, and tendons drastically reduces the time and effort required to dissect and study the structures associated with the subsequent systems. This scheme offers the advantage of mastering information about a single structure in totality within different regions, but in the context of a single functional system, in contrast to the traditional anatomy teaching which relies on providing information about a large number of functionally diverse structures that happen to run contiguously with a single region.

Furthermore, a complete knowledge of a structure in a system facilitates understanding of the anatomical basis of surgical procedures and disease processes. For example, the movement of a thrombus or embolus through a venous or arterial channel will be easier to understand when the learner is able to trace the venous or arterial route of the thrombus or embolus. As a unifying module, a system-based approach eliminates the need for a student to reconstruct the connections of structures taught in different regions and helps the learner to view anatomic structures as a continuum. This fact, as indicated earlier, may prove to be important when performing medical/surgical procedures, e.g. placement of a catheter or a central line.

This study aims to assess the impact of a system-based anatomycurricular changes on students' satisfaction and performance in local and national exams.To that end, student evaluations and exam performances for the academic year of 2005 and USMLE Step 1 scores prior to the curriculum change in anatomy (academic years of 2003–2005) were tracked and compared with those following the curriculum change (academic years of 2007–2010).

2. Rationale

The present trend of preclerkship curricula has been in flux for the past decade and the search for a unified medium where various first- and second-year disciplines can be horizontally and vertically integrated remains an important focus of current medical education. Since gross anatomy is the only discipline that is taught with a region-based approach, the ability to incorporate it into any form of integrated teaching model is limited. This inflexibility extends to the clinical clerkships and the ability of the learner to master surgical/medical procedures and associated complications as well as the systemic implications of disease processes. Further, a system-based approach encompasses spaced repetitions that enhance long-term retention of acquired knowledge and thus reducethe need for mass cramming. We believe, through this venue, the subject matter taught will be more persuasive and desirable and thus a system-based gross anatomy will have a far-reaching positive impact on students' learning and performance in the preclerkship and clinical years of medical education and national exams.

3. Materials & Methods

This study surveyed a demographically diverse student population from the academic years of 2005 through 2010.

This group consisted of a total of 480 medical students with a female/male ratio of 1:1.Gross anatomy lectures and laboratory sessions were delivered by faculty members from the Department of Pathology and Cell Biology and several clinical departments.Gross anatomy was taught in an integrated manner with microscopic, developmental, and radiographic anatomy. It is structured to precede information presented in physiology, neuroscience, and physical diagnosis.Teaching gross anatomy entailed lecture and rigorous laboratory dissection components that spanned an entire academic year from November to June.Figure 1-A & B shows the curricular structure pre- and post-changes to systemic anatomy.

August	September	October	November	December	January	February	March	April	May
Molecular Medicine *(Biochemistry & Genetics)*			*Anatomy* **Superficial back, axilla & brachial Plexus**, arm, forearm, wrist, hand, shoulder, associated muscles, nerves and vasculature **Thoracic wall,** cavity and superior and middle mediastina, lung, heart and major vessels, posterior thoracic wall and sympathetic trunk **Neck**- muscles, triangles, cervical plexus, larynx, trachea, esophagus, thyroid gland, nerves, vasculature.		*Anatomy* Abdominal walls, inguinal region, scrotum and testes, autonomics, stomach, peritoneum, peritoneal cavity and viscera, accessory glands of the digestion, lymphatics, intestine and posterior abdominal wall, kidneys, adrenal glands, diaphragm, vasculatures and lumbar plexus **Pelvis** in the male and female, pelvic viscera perineum **Lower extremity** Gluteal region, popliteal triangle, Anterior thigh, medial thigh, lower limb joints, leg and foot		*Anatomy* **Deep back**, Suboccipital triangle, spinal cord, meninges **Skull** osteology, cranial fossae. **Brain**, venous sinuses, vasculature & cranial nerves **Facial** and masticatory muscles, muscles of facial expression, parotid region, Autonomics of the head, temporal and infratemporal fossae **Root of the neck**, submandibular and submental triangles, oral cavity, pharynx, nasal cavity and palate, larynx		

Figure 1A

August | September | October	November | December	January | February	March | April | May
Musculoskeletal system • *Back, vertebral column and ligaments and suboccipital muscles* • *Scapular and pectoral muscles, axilla, clavicular and shoulder joints* • *Brachium- bone and muscles* • *Antebrachium-bones muscles, elbow joint and ligaments* • *Wrist joint, carpal bones, carpal tunnel, thenar and hypothenar muscles, intrinsic and extrinsic muscles* • *Thoracic wall, apertures and muscles* • *Abdominal walls, associated muscles, inguinal canal and hernias* • *Pelvic walls. apertures and associated muscles, pelvic and UG diaphragm* • *Gluteal region and muscles, ligaments, sciatic foramina, posterior thigh and Ischiocrural muscles* • *Hip joints, ligaments and associated dysfunctions* • *Anterior, medial and lateral thigh, associated muscles, femoral triangle, adductor canal* • *Knee joint associated ligaments, muscles and dysfunctions* • *Posterior leg and compartments* • *Anterolateral leg, compartments and associated syndromes* • *Ankle joint, ligaments and dysfunctions* • *Dorsum and plantar surfaces of the foot, associate muscular layers and ligaments*	***Nervous System*** • *Peripheral Nervous System* *Autonomic Nervous System* • *Spinal nerves* • *Cervical plexus* • *Intercostal nerves* • *Brachial plexus* • *Lumbosacral plexus* • *Cranial nerves* *Central nervous System* • *Spinal cord* • *Brainstem* • *Cerebellum* • *Diencephalon* • *Telencephalon* • *Brain, meninges, basal nuclei* ***Eye and visual pathways*** • ***Eye and extraocular muscles*** • ***Optic nerve, tract, optic radiation and visual dysfunctions*** ***Auditory System*** • *Ear* • *Auditory receptors, nuclei and ascending auditory pathways* *Vestibular System* • *Vestibular receptors* • *Vestibular nuclei and pathways* • *Vestibular dysfunctions* ***Sensory Systems*** • *General sensory System* • *Cortical sensations* • *Noncortical sensations* • *Motor Systems: Upper motor neurons, lower motor neuron & extrapyramidal system*	***Respiratory System*** • *Nasal cavity and olfactory system* • *Nasopharynx* • *Larynx and trachea* • *Bronchi & broncho-pulmonary segments* • *Lungs and pleura* • *Mediastinum* ***Cardiovascular System*** • *Pericardium & Heart* ***Arterial System*** • *Ascending aorta* • *Aortic arch and branches* • *Subclavian artery* • *Axillary, brachial, radial and ulnar arteries* • *Thoracic aorta & branches* • *Abdominal aorta and branches* • *External iliac, femoral, popliteal, anterior and posterior tibial arteries* ***Venous system*** • *Superior and inferior vena cavae and tributaries* • *Portal vein & tributaries* • *Porta-caval & cava-caval anastomosis* ***Lymphatic System*** • *Primary & secondary lymphoid organs*	***Digestive System*** • *Oral cavity and gustatory system* • *Oro-& Laryngopharynx* • *Esophagus* • *Peritoneum and peritoneal reflections* • *Liver and gallbladder* • *Omentum and omental bursa* • *Stomach and duodenum* • *Pancreas* • *Small and large intestine* ***Reproductive System*** • *Male internal reproductive system* • *Female internal reproductive system* • *Male and female perineum and associated spaces* • *Male and female external genitalia* ***Urinary System*** • *Kidney* • *Ureter and urinary bladder* • *Urethra in the male and female* ***Endocrine System*** • *Pituitary gland* • *Thyroid and parathyroid glands* • *Adrenal glands*

Figure 1B

Figures 1A & B: Diagrammatic representations of the region and system-based curricula for first-year medical students at the University of South Florida Morsani College of Medicine.

The region-based gross anatomy curriculum for the years that preceded 2006–2007 curricular change exemplified in the academic year of 2005–2006 was taught as part of Block B2 with the disciplines of physiology, physical diagnosis, longitudinal clinical experience (LCE), selected topics in radiology, embryology and histology. Neuroscience was taught separately in the following Block 3.

The region-based anatomy course spanned 19 consecutive weeks of didactic and laboratory instruction that followed the B1 block in which biochemistry and genetics were taught under “Molecular Medicine.”Each region was presented in two consecutive weeks with the exception of the abdomen, which spanned four weeks. Laboratory sessions scheduled for four hours. The class was divided into Teams A and B with each team attending half of the scheduled laboratory sessions. The nondissecting team conducted computer-based learning (CBL). Histology was instructed in a regular laboratory using optical microscopy. Practical exams were conducted using an essay format. Four multiple-choice-based examinations were offered during the time span of the course, with exams scheduled on various topics and at variable intervals covering disproportionate material, e.g. examination IV encompassed the anatomy of the leg, foot, head, and neck and renal physiology and body fluids.

Introduction of the superficial back occurred at the beginning of the course together with the shoulder joint and the physiology of action potentials, whereas the deep back was covered with the renal physiology, filtration, and clearance. Instruction of the “superficial” neck entailed coverage of the muscles and the cervical plexus immediately after the thoracic region separately from the deep “root” of the neck and the suboccipital region, which were introduced with the anatomy of the back and spinal cord toward the end of the course. The “superficial” neck was taught with cardiovascular physiology, whereas the deep “root” of the neck was introduced in conjunction with the physiology of acid-base balance. The anatomy of the abdomen and abdominal viscera was presented with the physiology of breathing; the pelvis and perineum were discussed with the physiology of the pituitary and adrenal glands. Interestingly, the anatomy of the gluteal region was placed after the anatomy and microanatomy of the male and female reproductive organs and before the perineum.

The physiology of pregnancy was taught with the gluteal region and popliteal triangle. Similarly the anatomy of the thigh and knee was discussed immediately before the presentations on the physiology of the pancreas and in advance of puberty and menopause. Microanatomy of the pancreas, thyroid, parathyroid, and pineal glands was offered in the same week but immediately after the presentation on the "thigh."

The anatomy of the skull, facial region, brain, dural sinuses, cranial nerves, and brain was presented in conjunction with the renal hormones and body fluid regulation. The physiology of electrolyte balance was taught sequentially with the skull, facial region, brain, cranial nerves, and the special sensory organs (eye and ear). The anatomy of the oral and nasal cavities and pharynx appeared with the acid-base physiology. The final week of instruction included the anatomy of the larynx and overviews of renal physiology.

To determine the final course grade the written and practical examinations were averagedwith the written exam receiving more weight in this calculation. A group written test was also offered after the completion of each block examination and utilized for grade adjustments.

Figure 1**B**: In the System-Based Curriculum, students cover structures within one system, revisiting structures associated with other systems so that material is repeatedly examined and reinforced throughout the year.

At the inception of the system-based module, a blueprint presentation was made to the departmental faculty, outlining the process,which requires the proposed restructuring, advantages of the system-based anatomy curriculum, and the mechanism of implementation.The process began with an extensive restructuring of the contents of all lectures and laboratory sessions. To that end, information about structures relative to the course, relationship, and function with associated images and clinical relevance are placed within the corresponding system.Lecture PowerPoint presentations were clearly defined with specific objectives.

At the beginning of the class, students were given an introductory presentation about the design of the course, objectives, and evaluation methodologies.Students were provided with a syllabus, a booklet of anatomic terminology, and sample questions.

To provide students with the opportunity to review material prior to the presentations and laboratory sessions, PowerPoint presentations were regularly posted during the week preceding the scheduled date and time of a lecture, and taught at least two days in advance of the laboratory session.These presentations were video-archived and supplemented with reviews, clinically applicable facts, and question-answer sessions.

During the restructuring phase, a 50% reduction in the anatomy dissection laboratory contact hours was achieved. Similar reduction occurred in microscopic anatomy contact hours due to the implementation of virtual microscopy.As part of the anatomy curricular restructuring, essay-based practical exams were eliminated and replaced by multiple-choice formatted practical exams to better utilize teaching faculty members' time, obtain timely accurate statistical performance data, eliminate subjectivity in grading, and reduce the time spent on interpreting students' handwriting and abbreviations.

For the laboratory component, an atlas, a newly written system-based and step-by-step dissection guide for each functional system, a structure list, and a pamphlet with laboratory rules and regulations were provided and posted on the course website. A series of step-by-step videodissections that correspond to the laboratory manual were recorded and posted.

The laboratory manual included an introductory surface anatomy followed by schematic drawings of incision lines and orderly instruction for dissection. Strict instructions were given regarding the dissection of the specific side of the body, and the designated cadavers where craniotomy, laminectomy, and pelvic bisection to be performed. Within the manual, a structure list was provided at the end of each section of a system. A videodissection of each scheduled laboratory session was recorded and posted on Blackboard prior to each session.

A total of 30 cadaveric stations were established with approximately six students per station.Additionally, two cadavers, placed in the center of the laboratory, were devoted to pre-laboratory demonstration of prosected structures.Bony skeletons and disarticulated bones were also made available for students.Students were able to view radiologic images of the relevant structures in the laboratory as well as in the lecture hall.

Laboratory sessions were organized to include Computer-Based Learning Activity (CBLA), medical procedures, and ultrasound sessions.CBLA encompassed a self-directed learning of sectional anatomy, dissection videos, and computer-based quizzes.Each laboratory session lasted for two hours for a total of 36 laboratory sessions with brief pre-laboratory demonstrations followed, in selected laboratories, by the applicable procedures and/or ultrasound presentations relevant to the area of dissection. All activities were video-archived and posted on Blackboard.

To facilitate active laboratory learning and to efficiently utilize the available space, students were divided into A and B teams with an equal number of students in each team.Students were also divided into 30 groups of six students with three students from Team A and three students from Team B.Only Team A or B attended a laboratory session with three students per group. Each group had a leader, who alternated for each assigned laboratory session. Accordingly, student groups in each team attended only 18 laboratory sessions out of the total of 36. When Team A attended the dissection laboratory, the nondissectingTeam B was engaged in a computer-based learning session.

For each assignment that followed, the leader from each group in Team A attended the first 10–15 minutes of the Team B laboratory session to review the structures dissected by Team A.This proved to be a successful approach to peer-to-peer teaching and leadership development[32].Upon completion of the review by Team A leaders, Team B started its dissection of the assigned area.During this phase, students in Team A were expected to perform a Computer-Based Learning activity. This alternate team activity continued through the duration of this course.

Structures encountered during the study of a specific system during dissection sessions, presentations, ultrasound, or procedure-basedactivities that pertain to systems other than the system under study were revisited and re-examined several times during the course of the study. To reinforce retention, learners were required to answer questions pertaining to previous systems in all the written and practical exams.

Prior to each practicum and written exam, students were provided with the opportunity to self-assess their knowledge base of anatomy through a practice practicum and question-answer sessions. Students were tested through eight multiple-choice formatted examinations (two for each systemblock) with written and practicum components.

Written and practical exams were conducted alternately between Team A and Team B. When Team A took the written exam, Team B took the practical examination and vice versa. In addition to identifying cadaveric structures, students were required to recognize structures in radiographic and histologic images during each practicum. Students were expected to answer each laboratory question within 55 seconds.At the conclusion of the practicum, an additional 10 minutes were given to students to revisit structures that they deemed difficult or required further examination. A comprehensive multidisciplinary end-of-the-academic-year examination that included the anatomical sciences (gross, developmental, microscopic, and neural anatomy) was conducted after the completion of systemblock examinations.

The final anatomy course grade was determined by averaging the written and practical examinations. A group test was offered after the completion of each systemblock examination in which students were randomly assigned to groups and required to discuss questions that were deemed challenging from the preliminary exam results data. They were asked to submit their answers as a group after a consensus had been reached.The results of the group tests were used to determine the validity of the questions and constituted (5–10%) of the students' exam score.

At the end of the academic year, students were required to fill out a questionnaire that rated the efficacy, quality, and structural design of various course activities.Additionally, students were expected to fill out a separate faculty evaluation form.Course evaluation was based on a 1–5-point Likert scale. Students' responses to the following questions were analyzed:"Rate the overall quality of the course," "Rate the structure and curricular design," and "Rate the usefulness of the system-based curriculum" (only students for the academic year of 2006 were given this prompt.)

A score of 5 indicated "excellent," a score of 4 denoted "very good," a score of 3 defined "good," a score of 2 signified "fair," and a score of 1 was designated as "poor." The mean score was determined for the questions "Rate the overall quality of the course" and "Rate the structure of the curricular design."These scores were normalized to the average scores for the same questions for the physiology course in order to rule out variation in evaluation style between the classes of students.An Analysis of Variance test was performed on the average Likert scale score for the anatomy course of all three academic years.T-tests were used to compare the meanfrom students for the academic years of 2006 and 2007 (system-based approach) to the mean from the academic year of 2005 (region-based approach).

In order to calculate the three-year average USMLE Step 1 score, the class average from each of the three years prior to the curricular change (academic years of 2003–2005) was compared to the class average of USMLE Step 1 from each of the three years following the curricular change (academic years of 2008–2010), using a T-test.

4. Results

We compared students' evaluations of the region-based anatomy curriculum to their evaluations of the system-based anatomy curriculum. The student rating from the classes of 2007 and 2008 of the overall quality of the system-based anatomy course was higher (26% and 16%, respectively) than that from the academic year 2005 of the region-based anatomy course (Figure 2).This positive trend continued through 2011.

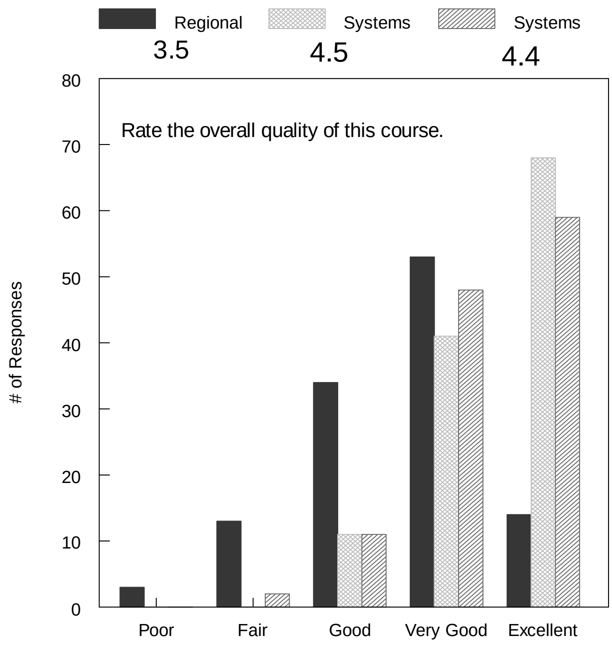

Figure 2

When we attempted to examine students' evaluations of the structure and curricular design we noted a similar trend.

On average, students' ratings of the system-based anatomy course for the academic years of 2007 and 2008 were significantly higher (40% and 25% higher, respectively) than those of the region-based anatomy course (Figure 3).

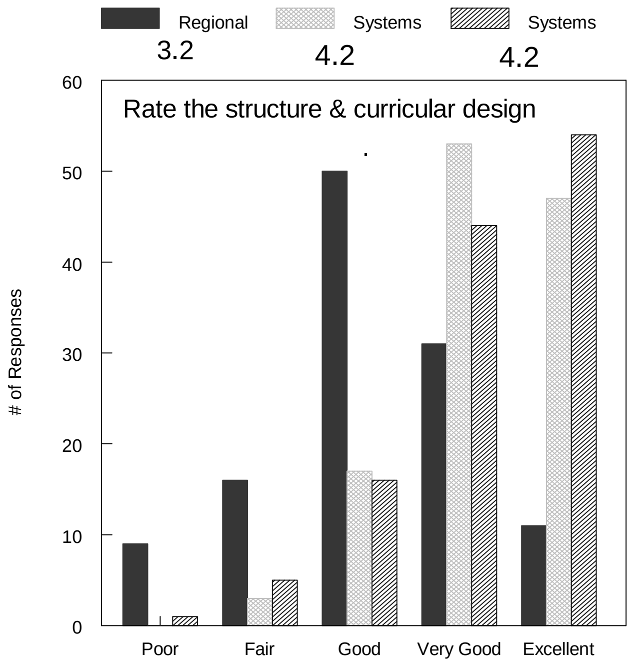

Figure 3

Furthermore, 92% of students' ratings of the usefulness of the system-based curriculum from the academic year of 2007 ranged between excellent, very good, and good, indicating that students predominantly responded positively to the newly structured curriculum.

We measured the impact of the anatomy curricular changes on student performance. No statistically significant trend was detected when compared to the scores in physiology (Figure 4).

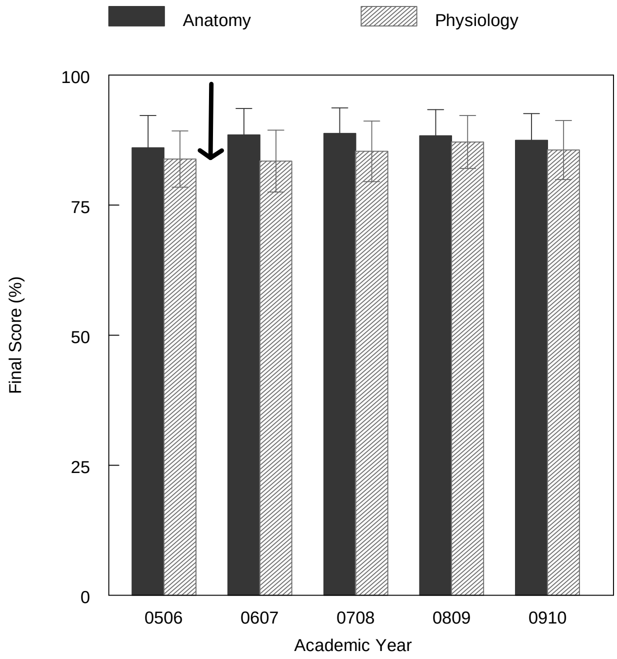

Figure 4

We also compared the average of the anatomy course evaluations before and after the curricular changes to the averages of all first-year basic science course ratings. Anatomy rating maintained an edge over all other courses taught during the first year (Figure 5).

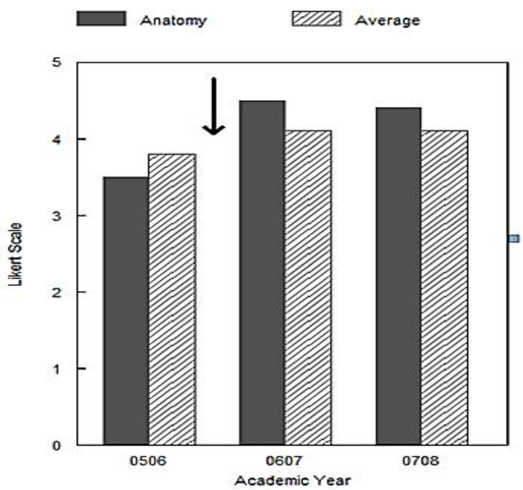

Figure 5

Students were asked to assess the usefulness of the system-based approach and the response was positive (91.7%), with 36.7% rating it as “excellent,” 35.8% as “very good,” and 19.2% as “good” (Figure 6).

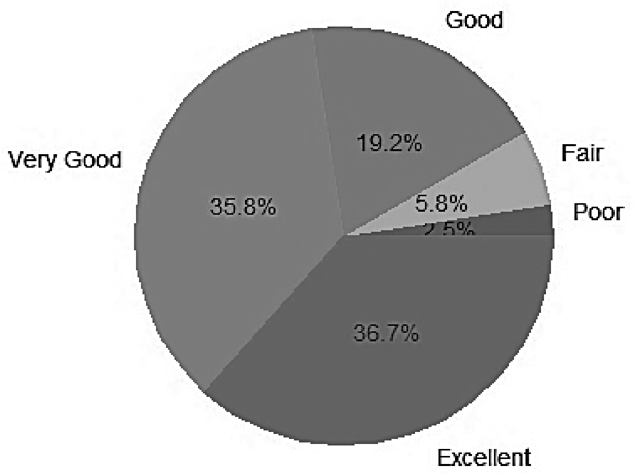

Figure 6

We also attempted to compare the average USMLE Step 1 scores from the three years prior to the curricular change to the scores from the three years following the curricular change.We did not observe substantial change when compared to the scores in physiology. However, the average USMLE Step1 & II scores for the cohort students following the implementation of the system-based curriculum showed a consistent increase and they were approximately three points higher than the average scores during the region-based curriculum (Figure 7).

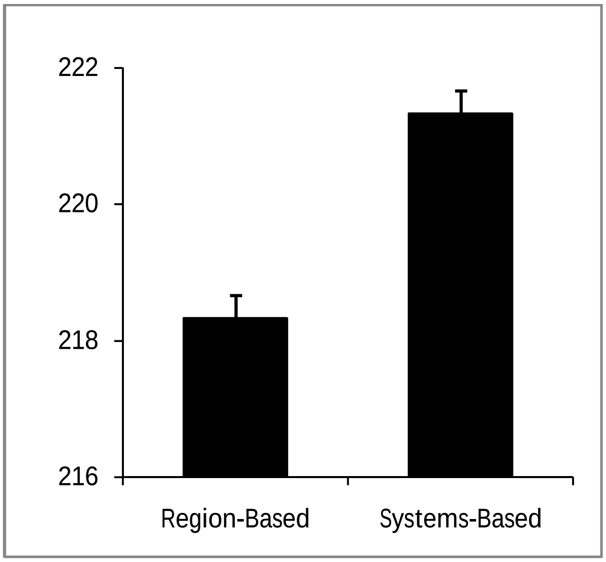

Figure 7

5. Discussion

Prior to 2006, the Gross Anatomy Course at the University of South Florida Morsani College of Medicine was taught within a region-based curriculum with a very limited degree of integration with the other first basic science disciplines of physiology, neuroscience, imaging, and physical diagnosis and even less so with the clinical disciplines. A students' survey confirmed major concerns regarding the pre-2006 curricular design, the limited multidisciplinary and clinical integration, the quality of lectures, and the lack of direction in the gross anatomy laboratory. Respondents also questioned the efficacy of exam questions in reflecting their knowledge base in gross anatomy and the disproportionate workload required to satisfactorily complete the course.

These concerns were compounded by the inability of anatomy as a discipline, within a region-based curriculum, to pattern itself to the evolving changes in curricular design and medical education.This inability stemmed from the fact that a single region in the human body contains structures with diverse paths, characteristics, functions, and relationships that belong to different functional systems, and are taught in different systems within other disciplines of the first-year curriculum.

The limitations in the ability of students to master large amounts of disjointed information presented within a region-based curriculum were echoed by students' responses from the academic year that preceded 2006 that questioned the efficacy of exam questions in reflecting their knowledge of the material presented.

The majority of students stated that they spent >15 hours per week studying anatomy and felt their effort was not reflected in their grades.Course rating was consistently low.The fact that a single region in the human body contains multiple structures that are taught in several different systems, different stages of education, and by several disciplines without a common thread, link, or reinforcing mechanisms for the information introduced posed a serious limitation for the learners was a also a serious concern for the students . These difficulties were heightened by the fact that learners had only one opportunity to master structures in each region. There was no follow-up or opportunity to repeat topics discussed in other regions.For the learner, this posed a limitation in his/her understanding of the conceptual basis of anatomic knowledge, appreciation of the course, relationships and functions of the structures covered, and the ability to understand the basis of medical procedures and systemic diseases.Further, students' exposure to brief facts about a large number of structures without the benefit of repetition and reinforcement posedadditional difficulty in their ability to master the information presented.

Since the introduction of an integrated knowledge of sciences basic to medicine dictates a clear conceptual understanding of the basis of medical procedures and systemic diseases, a transformation in teaching anatomy and accommodation of a system framework are needed. The perception of anatomy by other disciplines as an inflexible subject unwilling to lend itself to any form of curricular integration is an additional factor that made this change a necessity.

To that end, a well-designed system-based anatomy curriculum was introduced in 2006. Certain challenges arose during the implementation of this curriculum includinga scarcity of system-based resources, e.g. lab guides and textbooks, compared to the substantial educational tools available for traditional teaching and a degree of faculty resistance to this curricular change. However, some of these issues were tackled by the introduction of well-organized and efficiently delivered lecture presentations and a laboratory dissection manual.

We believe the initial resistance to the introduction of the new curriculum of some faculty members who were accustomed to the traditional curriculum came as a result of the misconception that a system-based approach to anatomy renders the donor body nondissectible for the study of subsequent systems and subsequently might adversely impact students' ability to learn. A presentation to the departmental faculty on the rationale for curricular restructuring, the introduction of a well-organized system-based syllabus, a step-by-step laboratory guide, restructuring of lectures, complete utilization of both halves of the cadavers in dissection and also by the use of prosected cadavers for structures that are not easily accessible in a particular system alleviated many of these concerns.

Student performance, course evaluation, and USMLE Part1 scores were tracked and compared for the academic years of 2005–2010. There was a consistent upward trend in student rating of the course and the quality of instruction compared to the years preceding 2006.The overall quality of the course remained the highest among all first-year courses since the implementation of the curricular changes in anatomy (Figure 5).Examination of the student survey reveals the presence of a correlate between teaching methods and student performance as it was substantially higher between 2006 and 2010 than in the years preceding 2006. Students' high perception of the course director's responsiveness was also matched by the overall positive attitude toward the course.

An upward trend in the USMLE scores observed in this study was seen following the switch to the system-based curriculum. This may also be attributed to concurrent changes in other preclerkship courses, pedagogy, examination methods, admissions policies, or other factors.

Our data show increased student approval of both the anatomy course and its curricular design following the institution of the systems approach (Figure 3). When we interpreted the success of the system-based curriculum through the data collected from student surveys we were cognizant of the difference in the style of student learning, exam design, and changes in total laboratory contact hours, and differing student preparation.For example, some, but not all, first-year medical students do not take anatomy prior to medical school.These differences may confound the interpretation of the data showing acceptance of the system-based curriculum.

However, the large number of students involved and the time span of this study, the consistent nature of the questionnaire, the steady and significant upward trend in course rating and performance, and the perceived high quality of lectures, in the absence of other major curricular changes, can be attributed largely to the change in the anatomy curriculum. The consistent upward trend in the results of USMLE-I (Figure 7) supports the view that a successful curricular change can reinforce the role that sciences basic to medicine play in student readiness for the study of the clinical curriculum. We believe the results were in line with the notion that a system-based approach prevents fatigue, inattention, and ineffective cognitive processing [12, 17,25, 42]. It provides the learners with realistic and a large number of practice opportunities. In addition, spacing through this approach enables the learner to improve performance by utilizing different mental contexts and perspectives when acquiring information 21, [46, 47, 48,23, 37]. It makes the subject matter and concepts presented more familiar, valid, and thus desirable and persuasive to the learners, prompting constructive learning approaches [10, 36, 50, 53]. Periodic repetition of the learning material through the duration of the academic year also enables the learner to employ a variety of cognitive processing and creative ways to prompt retrieval failure and retain acquired spaced knowledge [1,3]. It has been proposed by a number of investigators [31, 39] that spaced repetition interposed with sleep over a period of time affects memory in a positive manner.This has been attributed to the fact that sleep prompts learners to encode presented information in a retrievable manner.One might argue that spaced teaching in the system-based curriculum may induce retrieval failure when compared to the heightened sense of instantaneous remembering of information through massed and crammed repetition as in a region-based approach. This transient initial failure to retrieve spaced information is beneficial as it stimulates the learner to devote more time to processing the information and deeply searching for potent cognitive encoding strategies that engender long-term retrievability and thus the need for subsequent repetition that the system-based approach provides [3, 4].

The high level of attention given by the students to this model of anatomy teaching and the positive trend in learners' performance indicate that spacing in the system-based module plays a role in reducing the forgetting-curve.Knowing what was presented before and periodically repeating the previously introduced material in a different context is essential for understanding and retaining the material that will be presented at a later time.

Further, the introduction of ultrasound-based and procedure-based anatomy modules into the system-based anatomy curriculum reinforced with a robust feedback mechanism added spacing segments before and after each primary learning situation, and thus expanded retrievalpractice opportunities. This was also true for other activities introduced periodically, such as computer-based learning, videos, and reviews.

We believe the reduction in the length of laboratory sessions and the introduction of group leadership and peer-to-peer teaching greatly enhanced learners' interest and motivation and thus created a positive environment of collaborative learning.

The perceived response rate to course evaluation by certain students, the introduction of a multiple-choice formatted practicum, the correlation between the degree of student satisfaction and individual performance, and the difficulty with deciphering the precise impact of these curricular changes on the course ratings, USMLE Step-I and USMLE Step-II are factors to be considered in the evaluation of the results of the survey. However, the large number of students involved in this survey and the time span of this educational project, the extensive nature of the questionnaire, the positive trend in course rating and performance, the perceived high quality of the lectures and the relative increase in the overall USMLE Step-I scores, in the absence of major curricular changes in other disciplines of the preclerkship curriculum, can relatively be attributed, though not completely, to the change in anatomy teaching.

6. Conclusions

Based on students' perception of the system-based anatomy curriculum relative to other disciplines, their performance, and USMLE scores, we have demonstrated that a successful switch to a system-based curriculum can be achieved. We feel that this transformation is conceptually sound, practical, and proved to be valuable to students' long-term retention of information. Exposure to anatomical structures in the context of functional systems improves learners' outlook, motivation, and perception of anatomy as a crucial discipline in medical education. It readily enhances learners' understanding of anatomical structures as a continuum and thus promotes the mastery of medical and surgical procedures as well as disease processes.

Despite some limitations of the study,our findings indicate that a system-based anatomy curriculum is an efficient, versatile, and successful teaching module that effectively addresses the challenges of integration and clinical relevance. They indicate that integrating anatomy lectures and laboratory sessions with the system-based curriculum of the first-year basic sciences may enable students to better appreciate the mechanisms of human disease as they relate to the structure and function of the affected organs. Using a systems approach enhances the integration of anatomy with pathology, and clinical medicine, and provides students with a foundation for problem-based learning exercises and clinical reasoning.

The results of this study indicate that a system-based module is a dynamic method of teaching anatomy that can enhance student performance, and increase foundational knowledge while providing a positive outlook to medical curriculum.It also allows efficient utilization of available resources, e.g. cadaveric dissection, and widens the field for the introduction of medical procedures and diagnostic methodologies. To retain its relevance, in our judgment, anatomy must be open and flexible enough to adapt to the evolutionary changes in the medical curriculum.

References

Greiner A C., Knebel E. Health Professions Education: A Bridge to Quality. The National Academies Press. 2003. Washington, DC: International Standard Book Number 0-309-08723-6 (book): International Standard Book Number 0-309-51678-1 (PDF), Library of Congress Control Number: 2003106403.

Bilderback K, Eggerstedt J, Sadasivan KK, Seelig L, Wolf R, Barton S, McCall R, Chesson AL Jr, Marino AA. (2008). Design and implementation of a system-based course in musculoskeletal medicine for medical students.J Bone Joint Surg Am, 90(10):2292-300.

Saleh, H.A. (2011). Assessment of Anatomy Courses in a system-based medical education. Romanian Journal of Functional & Clinical, Macro- & Microscopica,10(2):161.

Shehnaz, S.I., J Sreedharan,andK G Gomathi. (2014). Does curricular change improve faculty perceptions of student experiences with the educational environment? A preliminary study in an institution undergoing curricular change.J Educ Eval Health Prof, 26:11:7.

Williams PC, Epps AC, McCammon S. (2011).The strategic impact of a changing curriculum and learning environment on medical students' academic performance. J Natl Med Assoc,103(9-10):57.

Hyona, J.; Niemi, P. (1990). Eye movements during repeated reading of a text.Acta Psychologica, 73:259-280.

Wagner, A D., Desmond, 1. E., Demb, 1. B., Glover, G. H., & Gabrieli, 1. D. E. (1997). Semantic repetition priming for verbal and pictorial knowledge: A functional MRI study of left inferior prefrontal cortex. Journal of Cognitive Neuroscience, 9: 714-726.

Bahrick, H. P., Bahrick, L. E., Bahrick, A. S., & Bahrick, P. (1993). Maintenance of foreign language vocabulary and the spacing effect.Psychological Science, 4: 316-321.

Bloom, K. C., & Shuell, T. 1. (1981). Effects of massed and distributed practice on the learning and retention of second-language vocabulary.Journal of Educational Research, 74: 245-248.

Challis, B. H. (1993). Spacing effects on cued-memory tests depend on level of processing. Journal of Experimental Psychology: Learning, Memory, and Cognition, 19:389-396.

Cohen MS, Yan VX, Halamish V, Bjork RA (2013). Do students think that difficult or valuable materials should be restudied sooner rather than later?J Exp Psychol Learn Mem Cogn, 39(6):1682-96.

Cull, W. L., Shaughnessy, 1. 1, & Zechmeister, E. B. (1996).Expanding understanding of the expanding-pattern-of-retrieval mnemonic toward confidence in applicability.Journal of Experimental Psychology, Applied, 2:365-378.

Dellarosa, D., & Bourne, L. (1985). Surface form and the spacing effect.Memory & Cognition, 13: 529-537.

Greene, R. L. (1989). Spacing effects in memory: Evidence for a two-process account. Journal of Experimental Psychology.Learning memory and Cognition.15:371-377.

Hintzman, D. L. (1974). Theoretical implications of the spacing effect. In R. L. Solso (Ed.), Theories in cognitive psychology: The Loyola Symposium, (77-99). Potomac, MD: Erlbaum.

Karpicke JD, Bauernschmidt A. Spaced retrieval: absolute spacing enhances learning regardless of relative spacing.(2011).J Exp Psychol Learn Mem Cogn,37(5):1250-7 32.

Kerfoot BP. Adaptive spaced education improves learning efficiency: a randomized controlled trial. (2010). J Urol.,183(2):678-81.

Logan, J.M., Thompson, A.J., Marshak, D.W. (2011). Testing to enhance retention in human anatomy.Anat Sci Educ,4(5): 243–248

Morris, P. Fritz, C. 0., Jackson, Nichol, E., & Roberts, (2005). Strategies for learning proper names: Expanding retrieval practice, meaning and imagery. Applied Cognitive Psychology, 19: 779-798.

Rothkopf, E. Z. (1968). Textual constraint as function of repeated inspection.Journal of Educational Psychology, 59: 20-25.

Russo, R., Parkin, A.1., Taylor, S. R., & Wilks, 1. (1998). Revising current two-process accounts of spacing effects in memory. Journal of Experimental Psychology: Learning, Memory, and Cognition. 24(1):161-172.

Brown AS, Jones TC, Mitchell DB. (1996). Single and multiple test repetition priming in implicit memory.Memory,4(2):159-73.

Carpenter, S. K., & DeLosh, L. (2005). Application of the Testing and Spacing Effects to Name Learning.Applied Cognitive Psychology, 19:619-636.

Clough RW, Lehr RP.(1996).Testing knowledge of human gross anatomy in medical school: an applied contextual-learning theory method.Clin Anat,9(4):263-8.

Tschernig T, Schlaud M, Pabst R. (2000). Emotional reactions of medical students to dissecting human bodies: A conceptual approach and its evaluation. Anat Rec, 261:11–13.

Smith, S. M. (1982). Enhancement of recall using multiple environmental contexts during learning.Memory &Cognition, 10:405-412.

Smith, S. M., Glenberg, A., and Bjork, R. A. (1978). Environmental context and human memory.Memory and Cognition, 6:342-353.

Chung EK, Nam KI, Oh SA, Han ER, Woo YJ, Hitchcock MA.(2013). Advance organizers in a grossanatomydissection course and their effects on academic achievement.Clin Anat,26(3):327-32.

Dinsmore CE, Daugherty S, Zeitz HJ. (1999). Teaching and learning gross anatomy: Dissection, prosection, or ‘‘both of the above?’’. Clin Anat, 12:110–114.

Xue G, Mei L, Chen C, Lu ZL, Poldrack R, Dong Q. (2011). Spaced learning enhances subsequent recognition memory by reducing neural repetition suppression.Journal of Cognitive Neuroscience, 23(7):1624-33.

Yeager VL. (1996), Learning gross anatomy: Dissection and prosection. Clin Anat 9:57-59

J Cogn Neurosci, 23(7):1624-33.

Yammine K. (2014).The current status of anatomy knowledge: where are we now? Where do we need to go and how do we get there? Teach Learn Med,26(2):184-8.

Theoret CL, Carmel EN, Bernier S. (2007). Why dissection videos should not replace cadaver prosections in the gross veterinary anatomy curriculum: results from a comparative study.J Vet Med Educ,34(2):151-6.

Winkelmann A. (2007). Anatomical dissection as a teaching method in medical school: a review of the evidence.Med Educ,41(1):15-22.

Reidenberg, J.S. & Laitman, J.T. (2002). The New Face of Gross Anatomy.The Anatomical Record. 269:81-88.

Krych AJ, March CN, Bryan RE, Peake BJ, Pawlina W, Carmichael SW. (2005). Reciprocal peer teaching: Students teaching students in the gross anatomy laboratory. Clin Anat 18(4): 296-301.

Fitzharris T: Survey of gross anatomy courses in the United States & Canada. The Anatomical Record, 253 (6): 162-66.