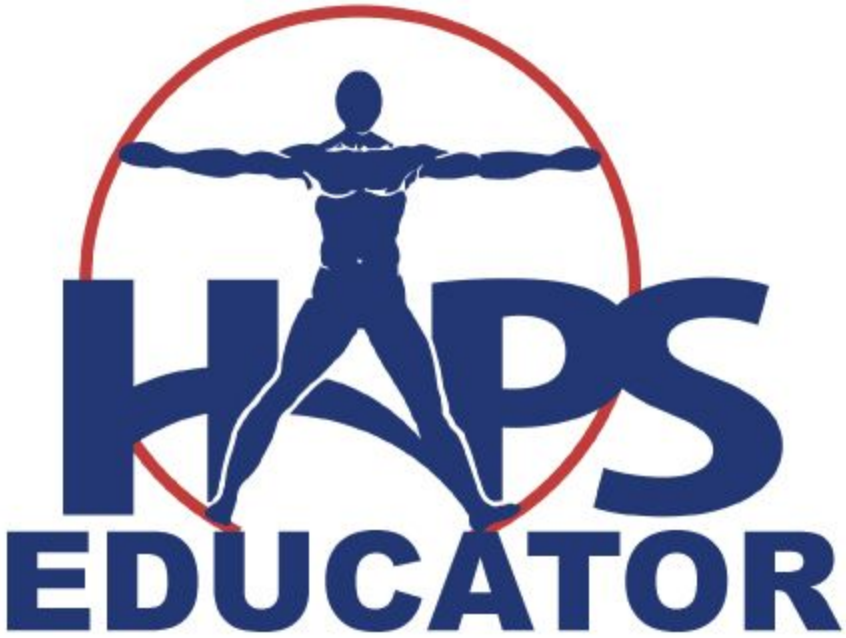
Student Perceived Difficulties in Learning Organ Systems in an Undergraduate Human Anatomy Course

Rebekah M. Lieu, Andrew Gutierrez and Justin F. Shaffer*

*Corresponding Author: j.shaffer@uci.edu

HAPS Educator. Vol 22, No. 1, pp. 84-92. Published April 2018.

doi: 10.21692/haps.2018.011



Lieu R.M. et. al. (2018). Student Perceived Difficulties in Learning Organ Systems in an Undergraduate Human Anatomy Course. *HAPS Educator* 22 (1): 84-92. doi: 10.21692/haps.2018.011

Student Perceived Difficulties in Learning Organ Systems in an Undergraduate Human Anatomy Course

Rebekah M. Lieu RN, BSN, Andrew Gutierrez BS, and Justin F. Shaffer PhD
Department of Developmental and Cell Biology, University of California Irvine, Irvine, California.
Correspondence to: Dr. Justin F. Shaffer, Department of Developmental and Cell Biology, 4234 McGaugh Hall, University of California Irvine, Irvine, CA 92697. USA.
j.shaffer@uci.edu

Abstract
Learning human anatomy may be a difficult task for students for a variety of reasons including the quantity of material in the course or discipline-specific factors such as understanding anatomical terminology or learning complex physiological processes. Additionally, students may find certain organ systems more challenging than others. While prior studies have assessed student perceptions of learning specific organ systems in a variety of settings, it is unknown what organ systems students in an undergraduate human anatomy course find most difficult to learn. The goals of this study were to determine what organ systems undergraduate human anatomy students find most and least challenging to learn and to determine the reasons why they feel as they do. The results of this study showed that students overwhelmingly found the peripheral nervous system to be the most difficult to learn because of complex structure-function relationships and their inability to visualize the system. Conversely, students thought that the cardiovascular and skeletal systems were the least challenging to learn because of prior exposure to them and ease of visualization. These findings allow for the development and alteration of instructional strategies to address the issues that students face when learning about difficult organ systems. doi: 10.21692/haps.2018.011

Key words: human anatomy, undergraduate education, student perceptions, assessment, organ systems

Introduction
Students may have difficulty learning the subject matter of the anatomical sciences. Reasons for this may include issues with motivation, course content, and the quantity of information. Bergman *et a*l. (2013) surveyed medical students' perceptions of a problem-based learning (PBL) curriculum and found that many students found anatomy boring and believed that it required self-discipline more than intellectual ability to learn the large quantity of information. However, students reported that when anatomy was taught in a clinical context it helped to increase student motivation and learning. At the college level, allied health students reported that discipline-specific factors, such as the need to learn muscle origins and insertions and the need to understand complex physiological processes like the cardiac cycle, were the most important reasons why undergraduate human anatomy and physiology courses are difficult (Sturges and Maurer 2013).

A survey of faculty members regarding the difficulty of learning human physiology found similar results in that faculty most commonly cited discipline-specific factors for why physiology is difficult to learn (Michael 2007). Students may perceive anatomy as purely an exercise in memorization, which may affect their attitude towards studying anatomy and lead to difficulties with the course (Miller *et al.* 2002). Undergraduate human anatomy students reported that the quantity of material presented in the course was what prevented them from learning anatomy successfully (Wright 2012). Due to these perceptions and other factors, undergraduate anatomy and physiology courses may have high drop out, failure, and withdrawal (DFW) rates (Harris *et al.* 2004, Sturges *et al.* 2016).

While these studies have demonstrated that students in general can perceive anatomy as difficult, students may find specific topics to be particularly difficult to learn for a myriad of reasons. If specific problem areas can be identified, then pedagogical tools can be developed to address them and improve student outcomes. Kramer and Soley (2002) surveyed second year medical students to determine what specific anatomical concepts were "problem topics." The pelvis was listed as problematic by 39 percent of students, while 35 percent found neuroanatomy problematic and 30 percent listed the perineum as difficult. In a survey of first-year dental students, Parkin and Rutherford (1990) found that while students enjoyed studying neuroanatomy, they found it difficult to learn.

At the pre-health professional level, Higazi (2011) reported that students enrolled in an introductory college-level human anatomy and physiology course found that histology was the most difficult subject to learn. In response, interactive imaging exercises were designed to improve learning outcomes. Gopal *et al*. (2010) surveyed introductory anatomy and physiology students and instructors and the majority of both groups responded that the cardiovascular system was most difficult to learn or teach. To address this issue, the researchers developed interactive web-based tools to improve cardiovascular system

continued on next page

instruction and found that students who used these tools significantly improved on summative laboratory assessments (Gopal *et al.* 2010).

While these findings suggest that students find certain anatomical topics more difficult than others, no studies to date have examined student perceived difficulties in pre-health professional human anatomy courses. This is an important subset of students to study since human anatomy is routinely taught at undergraduate institutions in the United States and student success in undergraduate anatomy has been linked to performance in medical school gross anatomy (Forester *et al.* 2002). The goals of this study were to determine what specific organ systems undergraduate human anatomy students found most and least difficult to learn and to determine why they held these perceptions. The results of this analysis can be used to design instructional tools or activities to address specific problem areas in teaching human anatomy at the undergraduate level.

Materials and Methods

*Course and participant descriptions***.**
This study examined a high structure undergraduate human anatomy course taught in the ten-week quarter system at a large research-intensive university in the southwestern United States. As a high structure course, the course included pre-class textbook reading, graded online assignments, individual and group active learning in-class, and graded weekly review quizzes (Shaffer 2016). The course included three 50-minute lecture periods a week and three hours of laboratory a week for a total of 25 hours of lecture and 30 hours of laboratory. The lecture portion of this course was taught by one of the authors (JS) with a systems approach. The course included pre-class textbook readings and graded online assignments, in-class active learning, and graded online weekly review quizzes. Trained graduate student teaching assistants taught the laboratory portion of the course. Laboratory guides designed to facilitate student interactions with plastic anatomical models and animal dissections (sheep brain, heart, and kidney) were used. Cadavers were not used in this course. For more information on this course, please see (Shaffer 2016).

The textbook for the course was Human Anatomy (7/e) (Marieb *et al.* 2014), which guides students through learning human anatomy system by system. The systems were taught in the following order: tissues and histology, integumentary system, skeletal system, muscular system, nervous system (central, peripheral, and autonomic), cardiovascular system, lymphatic system, respiratory system, digestive system, urinary system, and reproductive systems. The endocrine and immune systems were not taught. Table 1 provides a summary of the order of organ systems, the number of lecture sessions devoted to each system, the number of laboratory sessions devoted to each system, and the number of terms or structures that students were required to know about each system.

Table 1. *Order of organ systems taught in the course and approximate time devoted to each. The number of structures or terms that students were required to know about each organ system is also shown.*

Organ system	Number of lecture periods	Number of laboratory periods	Number of required terms or structures
Integumentary	1	0	37
Skeletal	5	2	317
Muscular	2	1	102
Central nervous	2	0.5	153
Peripheral nervous	3	0.5	159
Autonomic nervous	1	0	59
Cardiovascular	1.75	0.75	138
Lymphatic	0.25	0	10
Respiratory	1	0.25	65
Digestive	1	0.33	92
Urinary	1	0.33	39
Male reproductive	0.5	0.165	28
Female reproductive	0.5	0.165	30

continued on next page

This study surveyed 255 students in two sections of this course: Winter 2016 (n = 127) and Spring 2016 (n = 128). Students enrolled in this course were majoring in biological sciences (65.6%), nursing sciences (16.0%), pharmaceutical sciences (10.9%), or other (7.4%). The majority of the students were female (70.3%) and Asian (71.5%). The remaining ethnic breakdown was 13.3% Caucasian, 12.9% Latin@, and 1.6% African-American. A passing grade of "C" or better in a human physiology lecture course was a pre-requisite for enrolling in the course. The course was an elective for all majors except nursing science.

Data collection

This study analyzed data obtained from 255 students in two sections of this course: Winter 2016 (n = 127) and Spring 2016 (n = 128). To be included in this study, students had to give their consent, complete all major summative assessments (lecture and laboratory practical exams), and complete an end-of-course survey. Overall, 78% of students (n = 198) met these requirements and thus were included in this study. The data collected from each course section were combined in this analysis as similar results were obtained for individual sections. The Institutional Review Board of the University of California, Irvine, approved this study (HS# 2013-9959).

Data in this study were collected from an identifiable survey given online during the last week of the course after the last day of instruction had occurred. The survey was open for several days and closed before the final exam in the course. Students were asked to evaluate many components of the course including their perceptions of learning the organ systems of the human body. Students were asked to choose from a drop-down list which organ system they felt was most difficult to learn and which organ system they felt was least challenging to learn. They were also asked to explain their choices through two open-ended questions; one for the most difficult organ system and one for the least challenging organ system. Students were given points equal to 0.3% of their course grade for completing the survey.

Data analysis and statistics

Two analyses were performed in this study:

1) To determine what organ systems students perceived as most / least difficult.
2) To determine why students perceived organ systems as being most / least difficult to learn.

To determine what organ systems students perceived as most / least difficult, students chose a single organ system as most difficult and a single organ system as least difficult on the end of course survey (Table 2). Responses for each organ system were counted and are reported as a percentage of the total number of responses. Data were analyzed using Microsoft Excel 2011 (Microsoft, Redmond, WA).

To determine why students perceived a given organ system as most / least difficult, students wrote comments in the end of the course survey explaining their reasoning for choosing an organ system as most / least difficult.

An iterative qualitative analysis of the written comments, similar to that performed in previous studies, was performed by two researchers (JS and RL) (Welsh 2012, Heiner *et al.* 2014, Sato *et al.* 2017). Initially, student comments from the Winter 2016 course section (n = 196 comments; 98 each for most and least difficult organ systems, respectively) were read and coded independently by the researchers. They then met to discuss the emergent themes and agreed upon an initial set of themes. After reviewing the same set of comments, the researchers met again to discuss whether the initial set of themes was viable and whether changes were necessary. At this time, the initial set of themes was revised and the researchers agreed upon a final set of nine themes (Table 3). They then coded the student comments from the Spring 2016 course section (n = 200 comments; 100 each for most and least difficult organ systems, respectively). The data from both course sections were then combined to yield a total of 198 comments describing the most difficult organ system with 425 applied themes and 198 comments describing the least difficult organ system with 301 applied themes.

Inter-rater reliability was determined at the conclusion of the coding process. As comments tended to have more than one theme applied, inter-rater reliability was characterized in terms of a complete match (all assigned themes matched between the researchers), a partial match (some, but not all themes matched between the researchers), and no match (no assigned themes matched between the researchers). The researchers had complete matches with 70% of the comments, partial matches with 24% of the comments, and no matches with 6% of the comments. Any conflicts in themes were discussed until a consensus was reached.

continued on next page

Table 2. *Percentage of students reporting organ systems as most or least difficult. Organ systems are presented according to the order that they were taught in the course. Data are presented as a percentage of the study sample (n = 198).*

Organ system	Most difficult (%)	Least difficult (%)
Integumentary	4.0	3.5
Skeletal	1.5	24.7
Muscular	13.1	2.5
Central nervous	26.8	1.5
Peripheral nervous	30.8	0.0
Autonomic nervous	14.6	0.5
Cardiovascular	5.1	27.8
Lymphatic	1.5	1.0
Respiratory	0.0	5.6
Digestive	2.0	8.1
Urinary	0.0	6.6
Male reproductive	0.0	6.6
Female reproductive	0.5	11.6

Results

Most and least difficult organ systems

At the end of the course, students reported in an online survey what organ system they thought was most difficult to learn and what organ system they thought was least difficult to learn. As shown in Table 2, more than 61% of students reported that some aspect of the nervous system was the most difficult organ system to learn, with the peripheral nervous system (30.8%) being reported most often. Outside of the nervous system, the muscular system (13.1%) was reported most often as the most difficult organ system to learn. Conversely, Table 2 shows that the least difficult organ systems were the cardiovascular system (27.8%), the skeletal system (24.7%), and the female reproductive system (11.6%).

Emergent themes from student written responses

To determine why students perceived organ systems as most or least difficult to learn, students explained their reasoning in an online end of course survey. A total of 198 comments describing the most difficult organ system were analyzed and an identical number of comments describing the least difficult organ system were analyzed. After an iterative coding process, nine themes emerged that were applicable to why students thought organ systems were most or least difficult to learn. A summary of the themes is shown in Table 3 including the definition and a representative quote for each theme.

Table 3. *Emergent themes from analyzing written student comments.*

Theme	Definition	Example quote
Amount	Quantity of material to learn in the system	"There were a lot of structures and functions that went along with this system and if you didn't know it then it would be hard to follow the rest of section."
Complexity	How complex (or simple) the system was	"I think it was mostly difficult to put the pieces together; I feel that I understand material well if I can see that I can retain it, but with material from the central nervous system, I'm constantly forgetting details, all of which are important."
Familiarity	Prior exposure to the system	"I think it helped tremendously that I went over this in physiology before."
Interest	Enjoyment/personal interest in the system	"I am very active in working out and lifting weights so it was easy to correlate my workouts with the muscles we learned (and ones I was already familiar with) to the actions and functions."
Structure	Issues with system structures	"This was the most challenging because of the locations of the nerves and their paths/destinations."
Function	Issues with system functions	"The difference between muscular vs cutaneous innervations of spinal nerves were hard for me to grasp."
Terms	Issues with system terms (language)	"The terminology and naming the muscles was a little difficult for me to memorize."
Time	Amount of time required to learn system	"With the brain itself, it is so complex and complicated that it took me a lot of time to understand it."
Visualization	Being able to see system structures and/or use physical models	"I think it was the easiest because I could identify it on myself and it was easily identifiable on the skeleton models in lab."

continued on next page

Student perceptions of most difficult organ systems

To determine why students perceived certain organ systems as most difficult, written comments were sorted by organ systems and themes were applied to each comment. The fraction of student comments that were tagged with each theme is shown in Table 4 for the four most difficult organ systems (data for the remaining organ systems are provided in the Supplement).

The most difficult organ system reported by students was the peripheral nervous system (Table 2) and the most common themes for why students thought it was difficult were issues with structure and function. Students commented that there was a level of inherent difficulty in identifying and describing the structures and functions of the peripheral nervous system. They also had difficulty connecting the two systems, as in muscular innervation. Reasons for difficulty in learning the central and autonomic nervous systems were similar to those of the peripheral nervous system but a larger number of students cited issues with visualizing the autonomic nervous system. For example, students stated that they had trouble visualizing how signals traveled through the sympathetic trunks to their destinations. They felt that if more detailed models were present in the anatomy laboratory this issue may have been alleviated.

Students who reported that the muscular system was the most difficult to learn cited issues with structure and function (e.g. location of muscles and what motions they produced). More than half of students also commented that the number of muscles that they were required to know was large. In this course, students were required to describe 41 muscles by location and function.

Student perceptions of least difficult organ systems

To determine why students perceived certain organ systems as least difficult, written comments were sorted by organ systems and themes were applied to each comment. The fraction of student comments that were tagged with each theme is shown in Table 5 for the four least difficult organ systems (data for the remaining organ systems are provided in the Supplement). In contrast to the most difficult organ systems (Table 4), in which themes were applied fairly uniformly across organ systems (i.e. difficulties with structure and function), the reasons for why students thought specific organ systems were least difficult were very diverse.

The cardiovascular system was reported by many students to be the least difficult system to learn (Table 2). The most common theme for why students thought it was least difficult was because it was familiar to them (Table 5). Students reported prior learning associated with the cardiovascular system, notably in a required pre-requisite human physiology course. Students who chose the skeletal system as least difficult to learn commented that all they had to do was learn the specific bones and their markings. They mentioned that they had access to skeleton models in the laboratory portion of the course for visualization of the skeletal system, which made it easier to learn the required material. Reasons given for why the female reproductive system and the digestive system were least difficult to learn included familiarity with the system, lack of complexity, and ease of visualization.

Table 4. *Coding analysis of students' comments regarding the most difficult organ systems. The number of students who chose each organ system as most difficult is shown (n). The table reports the percentage of these students whose written comment included a given theme. Since some written comments had more than one theme applied, the percentages do not add up to 100% for each organ system. Data are shown for the four most difficult organ systems (data for the remaining organ systems are shown in the supplementary material).*

Theme	Peripheral nervous (n = 61)	Central nervous (n = 53)	Autonomic nervous (n = 53)	Muscular (n = 26)
Amount	42.6	37.7	31.0	53.8
Complexity	45.9	43.4	48.3	11.5
Familiarity	6.6	3.8	3.4	0.0
Interest	0.0	0.0	3.4	0.0
Structure	65.6	60.4	51.7	65.4
Function	45.9	41.5	37.9	65.4
Terms	1.6	7.5	17.2	3.8
Time	8.2	5.7	6.9	7.7
Visualization	18.0	9.4	34.5	0.0

continued on next page

Table 5. *Coding analysis of students' comments regarding the least difficult organ systems. The number of students who chose each organ system as least difficult is shown (n). The table reports the percentage of these students whose written comment included a given theme. Since some written comments had more than one theme applied, the percentages do not add up to 100% for each organ system. Data are shown for the four least difficult organ systems (data for the remaining organ systems are shown in the supplementary material).*

Theme	Cardiovascular (n = 55)	Skeletal (n = 49)	Female reproductive (n = 23)	Digestive (n = 16)
Amount	1.8	8.2	26.1	18.8
Complexity	23.6	51.0	30.4	50.0
Familiarity	90.9	18.4	78.3	62.5
Interest	5.5	12.2	21.7	6.3
Structure	0.0	10.2	4.3	12.5
Function	1.8	0.0	0.0	6.3
Terms	1.8	4.1	0.0	0.0
Time	0.0	4.1	0.0	0.0
Visualization	7.3	44.9	0.0	18.8

Discussion

Students enrolled in this undergraduate human anatomy course overwhelmingly reported that the nervous system was the most difficult organ system to learn due to issues relating to its complex structure-function relationships. These results agree with previous studies in which medical and dental students reported that neuroanatomy was one of the most, if not the most, difficult anatomical topic to learn (Parkin and Rutherford 1990, Kramer and Soley 2002). To a lesser extent, students reported that a lack of models and difficulty visualizing nervous system structures contributed to difficulties learning the nervous system. As being able to visualize anatomical structures through models or dissections has been shown repeatedly to benefit student learning (Kramer and Soley 2002, DeHoff et al. 2011, Lujan et al. 2013, Haspel et al. 2014, Lombardi et al. 2014), it does not come as a surprise that students would report this issue with regards to learning the nervous system. Indeed, undergraduate human anatomy students strongly favor the use of models when learning anatomy (Wright 2012, Anderton et al. 2016, Shaffer 2016).

Having found that students perceive the nervous system to be the most difficult organ system to learn allows for the development or incorporation of pedagogical strategies that can address the perceived problems. To address issues with structure-function relationships, activities may be developed that more explicitly link the connection between the function of the nervous system and the structures it acts on. For example, students cited that muscular innervation was a difficult concept to comprehend. A possible activity that could be used is to have students draw the descending pathway that upper- and lower-motor neurons are involved in to provide somatic motor innervation to a specific muscle. Additionally, clay modeling (Waters et al. 2005, DeHoff et al. 2011, Haspel et al. 2014) could be used to model spinal nerves traveling from the spinal cord to specific muscles. Shaffer (2014) previously developed a laboratory activity in which students use yellow string to model the paths of cranial and spinal nerves through the body by attaching the "nerves" to a skeleton model. These activities may thus help alleviate the issues with complex structure-function relationships and lack of visualization that students found when learning the nervous system.

Conversely, students found that the cardiovascular system was the least challenging organ system to learn primarily because of their prior exposure to this system via a human physiology pre-requisite course. Additionally, students are often exposed to the cardiovascular system (especially the heart) earlier in life and thus may acquire familiarity with the system over time, which may contribute to their perception of the cardiovascular system as less challenging to learn. To understand what students knew about the human body, Reiss and Tunnicliffe (2001) asked students (ranging from four-years-old to first-year undergraduate students) to draw what is inside the human body. They found that 93% of students drew some aspect of the cardiovascular system (nearly always the heart), which was the most commonly drawn organ system. This finding highlights that students of all ages are frequently exposed to the cardiovascular system, which again may contribute to students' familiarity with the system.

Some students found that the skeletal system was least challenging to learn primarily because it was easy to visualize either through palpating bones on their own bodies or by using skeleton models in the laboratory. This result is not surprising, as prior studies have reported that visualization is a critical component for successful learning of anatomy. Pandey and Zimitat (2007) reported that medical students identified that visualization was important towards successfully learning anatomy, in addition to understanding and memorization. Van Wyk and Rennie (2015) found that the majority of medical

continued on next page

students favored a dissection-approach to learning human anatomy. Dissection was not only applicable to their training but it also helped them visualize the structures of the body. In addition, a variety of models (plastic, animal tissue, computer, etc) have been reported to be useful for learning human anatomy in several different contexts (Lombardi et al. 2014) since models help students place objects or structures into forms that are more readily learned in a visual setting (Gilbert and Boulter 1998).

Limitations

A possible limitation of this study is that the data were collected with only one course design, topic sequence, and student population. The course was taught using high structure (Shaffer 2016) which required students to extensively prepare prior to each day of class by reading their textbook and completing graded pre-class assignments. Students also were engaged in active learning exercises in class to test their knowledge. In a course design with less structure (i.e. fewer pre-class assignments or less in-class active learning), students may find different organ systems as most or least difficult because they are learning about them in different ways. Additionally, the organ systems were covered in a systemic fashion starting with the integument, then skeletal, then muscular, etc, as is the norm in most undergraduate human anatomy textbooks. There could be a temporal effect related to the order that the organ systems were taught that could influence student perceptions of organ systems. Teaching human anatomy regionally or changing the order of organ systems would allow for the determination if the order of topic presentation affects student perceptions of difficulty. Lastly, this study only assessed one population of students at a large research-intensive university in the southwestern United States. The results of this study may vary if students from different populations, based on geographic location, institution type (e.g. community colleges), and course type (e.g. institutions where anatomy is a required course) are surveyed.

A second limitation is that the course in which this study took place required a human physiology pre-requisite course for enrollment. Therefore, students had prior knowledge of human physiology, especially of the cardiovascular, respiratory, digestive, and urinary systems, which often includes many aspects of human anatomy. This pre-requisite likely influenced the outcomes of this study, as >90% of students who chose the cardiovascular system as least difficult cited familiarity with the system as a reason why they thought it was relatively easy to learn about. This could explain the discrepancy with prior results showing that undergraduate students in an introduction human anatomy and physiology course found the cardiovascular system to be most difficult (Gopal *et al.* 2010).

Additionally, while the nervous system is taught in undergraduate human physiology courses, it is often taught focusing on neuron anatomy and physiology. Gross nervous system anatomy may be limited in undergraduate human physiology textbooks (Silverthorn 2016). In this case, the lack of prior familiarity with the anatomy of the nervous system may contribute to student perceptions of its difficulty. Repeating this study in introductory human anatomy courses that do not require a human physiology pre-requisite course would be warranted to determine the impact of prior knowledge on students' perceptions of anatomical organ systems.

Finally, students often cited the ability to work with anatomical models (the visualization theme) as a reason why the skeletal system was least difficult and the lack of models as a reason why the autonomic nervous system was most difficult. The availability of physical anatomical models in the laboratory portion of this course may thus have influenced the outcome of this study. While fully articulated and disarticulated skeletal models were available for student use, there were limited models of nervous system structures, mostly limited to those present in torso models with exposed brains and spinal columns. If additional and more descriptive nervous system models were available, students may have perceived the autonomic nervous system as less difficult to learn.

Conclusion

Student perceptions of difficulty in learning organ systems in a human anatomy course were evaluated in this study to determine why students think certain organ systems are more or less difficult than others. The major findings that students perceive complex structure-function relationships in the nervous system as most difficult and the skeletal system and cardiovascular system as least difficult, will allow for the development and incorporation of instructional activities and tools that can help address these problematic areas.

Acknowledgment

The authors would like to thank the graduate student teaching assistants of this human anatomy course for their dedication to teaching and student learning.

continued on next page

About the Authors

Rebekah M. Lieu, RN, BSN earned her bachelor's degree in Nursing Science from the University of California, Irvine. She is pursuing a career in pediatric nursing.

Andrew Gutierrez, BS earned his bachelor's degree in Human Biology from the University of California, Irvine. He is pursuing a medical career.

Justin F. Shaffer, PhD is an assistant teaching professor in the Department of Developmental and Cell Biology at the University of California, Irvine. He teaches undergraduate human anatomy, introductory biology, and non-majors science courses. He conducts research on the efficacy of high structure pedagogies in college science courses.

Literature cited

Anderton, RS, Chiu, LS and Aulfrey, S (2016) Student Perceptions to Teaching Undergraduate Anatomy in Health Sciences. *International Journal of Higher Education* 5:201-216. doi.10.5430/ijhe.v5n3p201

Bergman, EM, de Bruin, AB, Herrler, A, Verheijen, IW, Scherpbier, AJ and van der Vleuten, CP (2013) Students' perceptions of anatomy across the undergraduate problem-based learning medical curriculum: a phenomenographical study. *BMC Med Educ* 13:152. doi: 10.1186/1472-6920-13-152.

DeHoff, ME, Clark, KL and Meganathan, K (2011) Learning outcomes and student-perceived value of clay modeling and cat dissection in undergraduate human anatomy and physiology. *Adv Physiol Educ* 35:68-75. doi: 10.1152/advan.00094.2010.

Forester, JP, McWhorter, DL and Cole, MS (2002) The relationship between premedical coursework in gross anatomy and histology and medical school performance in gross anatomy and histology. *Clinical anatomy* 15:160-164. doi: 10.1002/ca.1114.

Gilbert, JK and Boulter, CJ. 1998. Learning science through models and modeling. In: B. J. Fraser and K. G. Tobin (Editors). International Handbook of Science Education. London: Kluwer Academic, p 53-56.

Gopal, T, Herron, SS, Mohn, RS, Hartsell, T, Jawor, JM and Blickenstaff, JC (2010) Effect of an interactive web-based instruction in the performance of undergraduate anatomy and physiology lab students. *Comput Educ* 55:500-512. doi: 10.1016/j.compedu.2010.02.013.

Harris, DE, Hannum, L and Gupta, S (2004) Contributing factors to student success in anatomy & physiology: Lower outside workload & better preparation. *Am Biol Teach* 66, 168-+. doi: Doi 10.1662/0002-7685(2004)066[0168:Cftssi]2.0.Co;2.

Haspel, C, Motoike, HK and Lenchner, E (2014) The implementation of clay modeling and rat dissection into the human anatomy and physiology curriculum of a large urban community college. *Anatomical sciences education* 7:38-46. doi: 10.1002/ase.1369.

Heiner, CE, Banet, AI and Wieman, C (2014) Preparing students for class: How to get 80% of students reading the textbook before class. *Am J Phys* 82:989-996. doi: 10.1119/1.4895008.

Higazi, TB (2011) Use of interactive live digital imaging to enhance histology learning in introductory level anatomy and physiology classes. *Anatomical sciences education* 4: 78-83. doi: 10.1002/ase.211.

Kramer, B and Soley, JT (2002) Medical students perception of problem topics in anatomy. *East African medical journal* 79:408-414.

Lombardi, SA, Hicks, RE, Thompson, KV and Marbach-Ad, G (2014) Are all hands-on activities equally effective? Effect of using plastic models, organ dissections, and virtual dissections on student learning and perceptions. *Adv Physiol Educ* 38:80-86. doi: 10.1152/advan.00154.2012.

Lujan, HL, Krishnan, S, O'Sullivan, DJ, Hermiz, DJ, Janbaih, H and DiCarlo, SE (2013) Student construction of anatomic models for learning complex, seldom seen structures. *Adv Physiol Educ* 37:440-441. doi: 10.1152/advan.00098.2013.

Marieb, EN, Wilhelm, PB and Mallatt, J. 2014. Human Anatomy. New York, NY: Pearson, p 859.

Michael, J (2007) What makes physiology hard for students to learn? Results of a faculty survey. *Adv Physiol Educ* 31:34-40. doi: 10.1152/advan.00057.2006.

Miller, SA, Perrotti, W, Silverthorn, DU, Dalley, AF and Rarey, KE (2002) From college to clinic: reasoning over memorization is key for understanding anatomy. *The Anatomical record* 269:69-80. doi: 10.1002/ar.10071.

Pandey, P and Zimitat, C (2007) Medical students' learning of anatomy: memorisation, understanding and visualisation. *Medical education* 41:7-14. doi: 10.1111/j.1365-2929.2006.02643.x.

Parkin, IG and Rutherford, RJ (1990) Feedback from dental students: performance in an anatomy department. *Medical education* 24:27-31. doi.10.1111/j.1365-2923.1990.tb02433.x.

Reiss, MJ and Tunnicliffe, SD (2001) Students' Understandings of Human Organs and Organ Systems. *Research in Science Education* 31:383-399. doi.10.1023/A:1013116228261.

Sato, BK, Lee, AK, Alam, U, Dang, JV, Dacanay, SJ, Morgado, P, Pirino, G, Brunner, JE, Castillo, LA, Chan, VW and Sandholtz, JH (2017) What's in a Prerequisite? A Mixed-Methods Approach to Identifying the Impact of a Prerequisite Course. *CBE Life Sci Educ* 16. doi: 10.1187/cbe.16-08-0260.

continued on next page

Shaffer, JF (2014) Plotting Cranial and Spinal Nerve Pathways in a Human Anatomy Lab. *CourseSource*. doi.10.24918/cs.2014.9.

Shaffer, JF (2016) Student performance in and perceptions of a high structure undergraduate human anatomy course. *Anatomical sciences education* 9:516-528. doi: 10.1002/ase.1608.

Silverthorn, DU. 2016. Human physiology: an integrated approach, 7th ed. San Francisco: Pearson/Benjamin Cummings.

Sturges, D and Maurer, TW (2013) Allied Health Students' Perceptions of Class Difficulty: The Case of Undergraduate Human Anatomy and Physiology Classes. *The Internet Journal of Allied Health Sciences and Practice* 11. Article 9.

Sturges, D, Maurer, TW, Allen, D, Gatch, DB and Shankar, P (2016) Academic performance in human anatomy and physiology classes: a 2-yr study of academic motivation and grade expectation. *Adv Physiol Educ* 40:26-31. doi: 10.1152/advan.00091.2015.

Van Wyk, J and Rennie, CO (2015) Learning Anatomy Through Dissection: Perceptions of a Diverse Medical Student Cohort. *International Journal of Morphology* 33:89-95. doi.10.4067/S0717-95022015000100015.

Waters, JR, Van Meter, P, Perrotti, W, Drogo, S and Cyr, RJ (2005) Cat dissection vs. sculpting human structures in clay: an analysis of two approaches to undergraduate human anatomy laboratory education. *Adv Physiol Educ* 29:27-34. doi: 10.1152/advan.00033.2004.

Welsh, AJ (2012) Exploring undergraduates' perceptions of the use of active learning techniques in science lectures. *J Coll Sci Teach* 42:80-87.

Wright, SJ (2012) Student perceptions of an upper-level, undergraduate human anatomy laboratory course without cadavers. *Anatomical sciences education* 5:146-157. doi: 10.1002/ase.1265.

Back to TOC