From Cadaver Dissection to Digital Anatomy: Benefits of Multi-Dimensional Learning Modalities

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Abstract

Digital anatomy programs such as the Primal Program™, BodyViz™, Complete Anatomy™, or Cengage™, provide rich learning opportunities with the ability to remove anatomical layers, highlight specific structures, and rotate images. However, supporting the diverse learning styles of today's anatomy students requires more than access to digital learning tools. This article describes sequential changes made in an anatomy course for a doctor of physical therapy (DPT) program. The DPT program moved from cadaver dissection to digital anatomy in the years 2020 – 2023. The most significant change was moving from the cadaver table, where there was rich student engagement during dissection, to a robust digital program with less student interaction and more screen learning. Throughout this transition, additional learning modalities were added. Tutorial stations were the most effective learning modality developed. At each station, faculty taught a focused topic (e.g. rotator cuff muscles), using multiple modalities such as a mounted skeleton, digital program, and Therabands™ to simulate muscles. Students learned how to integrate modalities and benefited from active engagement as faculty asked questions. These tutorial stations reinstated the learning environment of the cadaver tables and were optimal when students were allowed as much time as needed to gain confidence at each station. A post-survey sent to all enrolled students in the course each year identified the tutorial stations as the most preferred learning modality in 2023. To summarize, moving to a digital learning paradigm benefits from creative problem solving and persistent effort to support diverse student learning styles and student engagement. https://doi.org/10.21692/haps.2023.024

Key words: anatomy education, cadaver dissection, digital anatomy, multimodal learning styles, VARK

Introduction

This paper is about the simultaneous implementation of a digital anatomy platform with a change from cadaver dissection to observation of prosected material, from the perspective of an anatomical educator with decades of experience in cadaver dissection and demonstration. Successful implementation of this movement from the cadaver table to a digital anatomy platform required careful reflection on the elements of the cadaver experience most beneficial to teaching and learning as well as creative brainstorming on modalities that would provide similar pedagogical benefits outside of the cadaver lab. The hope is that sharing this experience provides insight to other educators in the midst, or considering, a similar pedagogical movement.

The Heart of Anatomical Education

Like many students struggling with their first dissection course, I (KT) found the experience confusing, frustrating, and bewildering as I tried to find and identify all of the small nerves, blood vessels, and muscles in a region of the body. When dissecting cadavers for the first time in graduate school, those of us assigned to each table learned to pool our resources and our wits, to tenaciously support each other by holding an atlas, reading the dissector, or taking a turn to dissect. This was especially important during times when we had to wait for a faculty member to assist us. The team assigned to each cadaver table were more than classmates; it was our hub as students. We supported and encouraged each other along the way.

As a young faculty member and throughout my career, the team concept at each cadaver table has been the pulse of the anatomy lab. As I supported student dissections on the assignment for that day, I was able to dialogue with students about the material, what they were looking for, the landmarks they thought would help them identify the structure(s) for dissection that day. Through these interactions, it was clear who was keeping up on the material and who was falling behind, who was struggling and who was appropriately confident. As an instructor, I knew the temperament or personality of each cadaver team. Knowing some cadavers provided greater dissection challenge than others, I knew which teams might have a greater need for more guidance and support.

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The cadaver experience itself conveyed an educational experience that is almost indescribable. While intimidating to some at first due to the smell, the sights, and the texture of human tissue, over time students became drawn into the amazing structures that compose the human body. The ability to feel the difference between an artery and a vein, to palpate the attachments of a muscle and understand its action based on those attachments, and to understand the impact of disease and pathology on anatomical structures, all leave an indelible mark. Cadavers represent the tremendous variability in human bodies; in a cadaver lab of one or two cadavers, there will be several "normal" variations (Erolin, 2019). Specific examples of diseases become engraved in memory because of the cadavers encountered at the dissection table. For many students, the cadaver experience is the first time they have been around a deceased person. When given some time to reflect, students find this part of the experience extremely valuable (Erolin, 2019).

Anatomical education has long been about much more than anatomical structures. These non-traditional, discipline-independent skills (NTDIS) include team learning, peer interaction, professionalism, and empathy (Lachman & Pawlina, 2022). Dissection skills, themselves, are taught by mentoring and close collaborations between faculty and students. In dissection-based anatomy, students have to learn to search for specific structures or relationships using relevant clues and landmarks along the way.

Anatomical education has a long history of innovation and adaptability (Hildebrandt, 2010; Trelease, 2016). There are many reasons for pedagogical movement away from the "gold standard" of cadaver dissection (Green & Whitburn, 2016; Green et al., 2018; Hisley et al., 2008). Anatomy without cadavers, or with less use of cadavers, is becoming a reality in both undergraduate and graduate teaching, as shown in a recent study that examined world-wide trends in anatomical instruction (Salinas-Alvarez et al., 2021). According to their research, a little more than half of graduate level anatomy courses taught in the United States practice cadaver dissection. This means that almost half use digital anatomy or other pedagogical techniques. In other countries such as New Zealand and Australia, the trend toward digital anatomy is amplified, and most students in graduate anatomy program do not dissect cadavers.

The anatomy course in the doctoral of physical therapy (DPT) program embarked on a similar pedagogical journey from cadaver dissection to a digital anatomy program. The following sections discuss the work by faculty in the DPT program to identify the critical components of the anatomy course and to replicate them with new modalities. Every anatomy course is unique in the resources that are available, and because the skills and talents of the teaching staff differ, the process and outcome of a pedagogical transition will be different. One goal for this paper is to encourage others engaged in a similar transition to think reflectively and plan creatively in this process.

Digital Anatomy

The first goal of the transition in DPT anatomy was to incorporate a digital anatomy platform. This is appropriate since anatomy, and the health science careers it supports, are becoming more and more digital. In some places even now, digital imaging is available at the hospital bedside and health care providers need an understanding of anatomy through the lens of digital technology (Erolin, 2019; Wickramasinghe et al., 2022). The development of robust digital programs for learning anatomy has steadily increased over the past decades and there are many options to consider. For example, there are digital anatomy tables such as Anatomage™ which provide a digital means to dissect body structures as well as study pathology and normal human variation. This is an engaging way for students to dissect without the cost and exposure to toxic chemicals such as formaldehyde.

There are many web-based digital anatomy programs that students can access outside of class or lab times. Selecting the one that delivers high quality anatomical engagement and meets program or course objectives can be challenging. Several studies have reviewed these programs and made suggestions (Hisley et al., 2008; Sugand et al., 2010; Temkin et al., 2006). In summary, programs that allow three-dimensional rotation and removal of layers offer significant learning benefit for students. The ability to customize tools and the ease of navigation are also important elements to consider (Havens et al., 2020).

The Primal Program™ (Anatomy.TV™) was selected for the DPT program and has met the needs of the students well. It offers a variety of systems and regionally based anatomy apps. The 3DRealTime app, a part of the Primal Program™, has been the cornerstone of the anatomy course because it allows rotation, layering, or isolation of structures. Structures can be easily added, deleted, or labeled. Images from the program have been easy to integrate within teaching materials, quizzes, or exams on our learning management system, Canvas.

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Ironically, the first semester that the Primal Program™ was adopted was the spring of 2020, when the Covid pandemic began. The cadaver lab was inaccessible and the digital program became the primary learning modality. This facilitated overcoming the learning curve with the Primal Program™ because of the amount of time we spent using and teaching with the program. It was clear that there is a significant learning curve to using any digital anatomy program. This shouldn't be surprising since cadaver dissection also has a learning curve in which students gain skills through dissection. To facilitate the digital learning curve, an extensive two-week training was developed with step-by-step instructions on how to use the apps and tools in the program. This replaced the part of the lab schedule where cadaver dissection was previously introduced. Thus, a digital anatomy tool may include as much of a learning curve as cadaver dissection.

To guide students during each lab, a lab handout was created using images from the Primal Program™ and instructions to digitally dissect. Each handout was loaded on Canvas at the beginning of the term. Images from the handout were also incorporated into a weekly practice quiz that modeled the types of questions and responses students would be expected to answer on a lab practical exam.

Despite these efforts to anticipate student needs and provide quality guidance, student and faculty engagement was not as robust as it had been in the cadaver lab. The ambience of the course was quite different. When some students struggled academically, faculty were not well enough experienced in using the new pedagogy to support them. One of the common challenges faced by DPT students in the first semester was managing the volume and pace of the material. Additionally, some students had not been in an academic environment for several years and they found it difficult to recall basic science information. Students often relied on passive learning by watching video files or reading power point slides. Some students were successful with this strategy; others struggled considerably.

Once there were low quiz or exam scores indicating that a student's academic performance was below minimum standards, faculty in the DPT anatomy courses met with that student, asking very open-ended questions about their study strategies. This provided an opportunity to point out academic resources in the course or the institution that were available if the student needed support, and to understand any non-academic life circumstances that were affecting their performance. These valuable conversations often revealed that students were spending a lot of time studying, but in an ineffective way, such as simply re-reading slides.

It was common for students to compare the amount of study time and study strategies to peers in the classroom, The students assumed this would give them success. Not only were struggling students academically unsuccessful, they were also not developing the discipline-specific strategies necessary for future courses. As a discipline, physical therapy is very hands-on, tactile, and kinesthetic in evaluating and treating patients. In the absence of dissection, and with the emphasis on digital anatomy, the course needed to develop additional learning modalities that would build successful learning strategies for physical therapy as a discipline, as well as for the anatomy course. These strategies will be discussed in the following sections.

Active Learning

The Department had previously used the VARK™ survey (https://vark-learn.com/the-vark-questionnaire/) to evaluate student learning preferences. There are many good learning style surveys available, and VARK™ has been validated as an appropriate survey for physical therapy students (Stander et al., 2019). VARK™ describes learning styles as visual, auditory, reading/writing, or kinesthetic. Multimodal learning styles are also evaluated. The VARK™ survey became a roadmap to assess the learning styles and pedagogical modalities needed to meet student learning needs. Literature supports that physical therapy students learn best when engaged in kinesthetic, hands-on activities (Good et al., 2013; Stander et al., 2019). Good et al. (2013) found a significant negative correlation between a kinesthetic learning style and academic success in anatomy. Thus, a digital anatomy program, by itself, may not engage all learners in deep learning. Understanding the learning styles of students in the DPT cohorts was essential to assessing the effectiveness of the modalities implemented.

Each anatomy class was invited to take the VARK™ survey. These data were de-identified and expressed as the percentage of the cohort for each trait (data not shown). The data indicated that 71% of DPT students at this institution were multimodal learners with 98% of all physical therapy students having a kinesthetic component to their learning styles. This may explain why some students specifically struggle with screen learning, stating that they spend much time studying, but "nothing sticks". Faculty realized that additional modalities that promoted active learning were needed.

Several iterations of active learning were used before identifying the best approach for this DPT program. Early on, students worked in lab groups of six students per group. Each lab group was assigned three topics and they were tasked with creating digital images with a question and answer for each topic using the digital anatomy program. The goal was to have students work in a small group to digitally dissect and engage with material by developing questions and images. This experience was beneficial in developing peer support, peer learning, and engagement with material. However, it was still screen learning.

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Clay modeling was added for one year (2021). This was very helpful for some students; however other students found it frustrating and unhelpful. The clay didn't always stick to the mounted skeleton, or the non-drying clay was stiff and sometimes difficult to mold to the correct shape or structure. When the students used clay, there was greater focus on using the clay than on learning what it represented. Clay modeling is still used for specific ligaments (e.g. medial collateral ligament or lateral collateral ligaments of the ankle joint) or small muscles (e.g. rotator cuff muscles). Demonstrations are usually set up by faculty within the lab and used on lab practical exams.

Over time, the image of a successful student in the context of the new pedagogy began to emerge. Successful students integrated bones, mounted skeletons, and models with the digital anatomy program. They had multiple modalities at the lab table and made integrative notes to study from. Struggling students had separate files for lecture notes, lab images, and muscle attachments and innervation. The DPT anatomy course has always asked integrative questions on exams. For example, marking the median nerve and asking, "Identify one muscle innervated by this nerve." This is an example of higher reasoning skills necessary for use in the clinic. For example, when a patient has atrophy of specific muscles or weakness in specific movements, a clinician identifies the affected muscle(s), the nerve that innervates these muscles, and potential sites of entrapment or injury. Faculty routinely asked questions similar to this in their discussions with students at the cadaver table. In the move to digital anatomy, when students focused on their computer screens, the ability to model integrative learning through discussion was more challenging.

As each term progressed, faculty developed and led tutorial stations where this integration was modeled by faculty using multiple modalities to explain a specific topic and engage in discussion with students. For example, one faculty member might hold a tutorial station focused on the rotator cuff muscles. They might have a scapula, humerus, and clavicle at their station, a mounted skeleton, and the digital anatomy program. Strips of Theraband™ could be used on the mounted skeleton to simulate the muscles. By placing one end of the Theraband™ on the origin and the other end on the insertion, students could simulate muscle attachments and movements. This could be compared with images from the digital anatomy program. Students could then work with the individual bones (e.g. humerus) and integrate the information. A successful student should eventually be able to look at an individual structure (e.g. lesser tubercle of the humerus) and visualize the span of the entire muscle attached to that tubercle, its action(s) and its innervation.

Eventually, these tutorial stations become the most effective teaching modality as perceived by students. These tutorial stations have filled the gap for instructor engagement with students, asking questions, assessing knowledge, and encouraging students to think more deeply about the material. They have been extremely successful when offered during open labs, when students can select the topics they need help with the most and can stay at the tutorial station for as long as they want. The groups at each tutorial station are also smaller during open labs, facilitating discussion.

Evaluating the success of tutorial stations using grades or performance scores is difficult. In a DPT course, the goal is for all students to have sufficient resources to pass and continue in the program. Student motivation is high to do well and grades tend to be strong. Attendance is also required at all labs and lectures. Open labs and cadaver observation are optional to attend, but may be required if students participate in academic tutoring. Often in a graduate anatomy course, the challenge is not to improve the grades of the entire cohort, but to focus on the struggling students, one at a time if necessary. If a student struggles throughout the anatomy course, but in the process gains new strategies for learning that will help them finish the program successfully, this is a success.

Peer Learning and Peer Support

Peer learning support was also important to student success. Lab groups are now organized around the bone boxes instead of the cadaver table. These lab groups meet during regular lab sessions and for a review each Friday. During the Friday review, stations with two mock practical questions are set up. Lab groups have five minutes to answer the question. Answer keys are provided to guide students on what constitutes a complete answer on the lab practical exams. Overall, these lab groups have provided an avenue for students to support each other and learn collaboratively.

Survey to Evaluate Pedagogical Effectiveness

A survey (Table 1) was developed to assess student perceived effectiveness of each learning modality. IRB was consulted before the data were collected. The survey was classified by IRB as action research which does not fall under the oversight of IRB at this institution. Each semester, the survey was sent to students after final grades were posted. Data were collected using a 5-point Likert scale (1 = was confusing or made learning more difficult, 2 = not very helpful, 3 = did not help or hurt, 4 = somewhat helpful, 5 = extremely helpful) and are expressed as the average (Table 2). In 2021, COVID-induced restrictions on lab access and face-to-face learning significantly impacted the anatomy course. This made comparison of any data from 2021 to other semesters extremely difficult. For this reason, data from 2021 is not included.

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Question	Assessed
In previous anatomy courses, which learning modality did you use?	Multiple choice (check all that apply)
In a previous anatomy course, if you used a digital anatomy program, how helpful was it?	5-point Likert scale
In a previous course, how helpful was learning from a cadaver (whether observation or dissection)?	5-point Likert scale
This semester, how did the Primal program™ impact your ability to learn anatomy?	5-point Likert scale
This semester, how did cadaver observation impact your ability to learn human anatomy?	5-point Likert scale
This semester, how did the "stations" or "tutorials" during the open lab time (3-5pm) impact your ability to learn anatomy?	5-point Likert scale
What is your most preferred (#1) learning modality?	Multiple choice (2023 only)
What is your second most helpful modality in learning anatomy?	Multiple choice (2023 only)
Please select all modalities that you feel are beneficial and should be used in a future semester (select all that you feel we should keep in the course).	Multiple choice (check all that apply; 2023 only)

Table 1. *Survey Questions (2023)*

Data (Table 2) demonstrated that student perceptions continued to shift positively towards use of the Primal Program™, with the average increasing from 4.41 to 4.51. The addition of the tutorial stations was also seen as very positive. The addition of the open lab time with the stations increased the average from 4.18 in 2022 to 4.56 in 2023. The anatomy course continues to use cadavers, but as an optional learning experience. The cadaver lab is available for the DPT course early in the morning, before lecture and lab; student comments indicated that the early time was a deterrent for some. Cadavers are not used in testing, which may decrease student motivation to spend time in the cadaver lab. Student comments indicated that the cadaver lab is a valuable experience, but is not as great a focus for their time or energy. These factors are demonstrated as a declining helpfulness of the cadaver experience from 4.68 in 2020 to 3.49 in 2023.

Statement	2020* (n = 46)	2022* (n = 43)	2023* (n = 39)
This semester, how did the Primal program™ impact your ability to learn anatomy?	4.41 $\pm$ 0.92	4.36 $\pm$ 0.65	4.51 $\pm$ 0.64
This semester, how did cadaver dissection (observation) impact your ability to learn human anatomy?	4.68 $\pm$ 0.68	4.21 + 0.84	3.49 $\pm$ 0.84
This semester, how did the "stations" impact your ability to learn anatomy?		4.18 $\pm$ 0.83	4.56 $\pm$ 0.71

*values are mean $\pm$ SD

Table 2. *Impact of learning modalities in the DPT anatomy course. For those questions using a 5-point Likert scale, 1 = was confusing or made learning more difficult, 2 = not very helpful, 3 = didn't help or hurt, 4 = somewhat helpful, 5 = extremely helpful. As a note, in 2022 and 2023, cadaver observation was optional only; therefore, not all students were exposed to cadaver anatomy, and this may have affected their response.*

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In 2023, students were asked to rank the learning modalities in order of helpfulness (Table 3). The tutorial stations received the highest ranking of 33.3%. The second choice of learning modalities was a tie between the Primal Program™ (18.0%), and the stations, lecture notes, and the daily lab manual (15.4% each). Student responses indicate that the bone boxes were not often used to study; however, the tutorial stations included the use of bone boxes and mounted skeletons, so students used bones for study, but possibly not from the assigned bone boxes. Student responses indicate that all learning modalities were beneficial and should be retained. These data support the benefit of multiple learning modalities to support student success in a graduate anatomy course (Rizzolo et al., 2010).

Conclusion

Cadaver dissection or observation of prosected material has historically provided a deep and rich learning environment for anatomy students, with modalities for all learning styles (Green et al., 2018; Green & Whitburn, 2016; Hisley et al., 2008). A pedagogical shift to a digital anatomy program should be carefully evaluated and implemented to ensure that multi-modal learning experiences are provided and that student learning styles and learning needs are met. There is not a "one size fits all" approach to anatomy (Good et al., 2013; Stander et al., 2019).

Literature in anatomical pedagogy has demonstrated the benefits of multimodal learning opportunities for students (Rizzolo et al., 2010). Kinesthetic learners, especially, may struggle with anatomical terminology and concepts (Good et al., 2013). This study supports the use of multimodal learning modalities in a doctoral program of physical therapy. In 2023, of a list of nine learning modalities and study aides, all were selected as worth keeping. The development of multimodal modalities began after the movement from cadaver dissection to a digital anatomy program and took several years to complete. Additional modalities such as silicone SynDaver™ upper limb and lower limb models continue to be added. Thus, it takes time to develop a multimodal approach.

For anatomy in a professional program such as DPT, transitioning curriculum from cadaver dissection to digital anatomy requires careful consideration of multiple modalities. Given that students are continuing to catch up on study skills and learning techniques lost during COVID-induced distance learning, a careful approach to multimodal learning and hands-on, kinesthetic experiences will benefit student learning and preparation for later clinical experiences.

For some students, a one-on-one approach is most beneficial and may be necessary. This may especially be the case for students who are primarily kinesthetic learners. These kinesthetic learners may not know how to implement

Learning Modality	Most preferred*	Second preferred*	Retain for next year, choose all that apply*
Cadaver	0	5.13	7.58
Primal program	20.5	18.0	12.6
"Stations" or "tutorials" during open lab (3-5pm)	33.3	15.4	11.6
Lecture notes	12.8	15.4	11.6
Lab PDF files or checklists	10.3	15.4	11.6
Weekly practice practical exams on Canvas	2.56	10.3	13.4
Friday review	12.8	12.8	10.1
MP4 files	7.69	7.69	9.39
Bone boxes	0	0	11.2

*values are % of responses

Table 3. *Most preferred (#1) and second preferred (#2) learning modality in(2023 (n = 39 respondents).*

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kinesthetic study strategies and may benefit from one-on-one tutoring as they develop these skills. The tutorial stations during lab and in the open labs provided a faculty hub for engagement with students, mirroring the experience around the cadaver tables during dissection. By continuing these tutorial stations during open lab, students who grasped material quickly or felt confident in their learning left the tutorial sessions, providing students who wanted more support in a smaller group setting with better access to faculty.

A transition from cadaver dissection to other modalities can be successful but may require several years to fully implement. Requesting and responding to student feedback may be a helpful component of this process.

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