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Dr. Stacy Reeder, Chair

Dr. Nancy Halliday, Co-Chair

Dr. Ji Hong

Dr. Daniel O'Donoghue

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Abstract

The COVID-19 pandemic forced academic institutions fully online in March of 2020. At the University of Oklahoma Health Sciences Center, anatomy faculty prepared for remote delivery of the Clinical Anatomy curriculum for newly matriculating dental and PA students. Faculty created dissection videos and synchronous lesson plans for lecture and laboratory video review sessions. Two purposes of this research were to assess academic outcomes and survey student perspectives of remote Clinical Anatomy. A third purpose was to determine relationships between outcomes and perceptions. Summative and formative assessment items were compared between a 2020 remote and a historical 2019 face-to-face cohort. For the 2020 remote cohort, a survey was developed to assess student perspectives of anatomical knowledge. Results indicated an increase in academic outcomes for the 2020 remote cohort. Remote students reported adequate cognitive domain gains in anatomical knowledge, but many perceived a lack of psychomotor and affective domain learning as a lost opportunity. Anatomy educators should seek online teaching pedagogies that support different modalities of student learning, and administrators need to consider student learning needs beyond the cognitive domain in order to promote teaching methods that develop professionalism and non-traditional discipline-independent skills (NTDIS).

Chapter 1: Introduction

Health professions education (HPE) programs have a unified goal of producing competent, thoughtful clinicians. Though the specific competencies vary according to profession, HPE programs generally share a standard curricular structure. Pre-clinical, basic sciences are typically presented early in the program to provide a knowledge base and vocabulary for the future clinical phase. The clinical phase allows for supervised development and application of clinical reasoning, communication, and procedural skills. Throughout both phases, educators model tacit skills of professionalism, ethical behavior, and interpersonal skills necessary for successful patient care. Accrediting bodies specific to each profession provide broad program goals such as demonstrating evidence of teaching critical thinking as well as curriculum content requirements of varying specificity. Within this general framework and accrediting standards, universities have the freedom to tailor their programs to student and community needs. Dental and physician assistant (PA) programs illustrate the variation possible within this framework.

General dentistry is a four-year program. The first two years of dental school are primarily didactic, with basic sciences such as anatomy a main focus. Dental students may take courses with medical or PA students during this phase. Dental programs may offer short, introductory clinical experiences in the pre-clinical years to help students situate their basic science knowledge within a clinical context. Years 3 and 4 are when students participate in community-based clinical experiences, with more autonomy granted to fourth year students. The inclusion of clinical experiences within the standard pre-clinical phase (and vice versa) is a common definition of integration (Brauer & Ferguson, 2015). Integration in the didactic phase also helps students see the usefulness of information seemingly unrelated to dentistry, a concept that many newly matriculated dental students struggle with (Henzi et al., 2007). Dental students must pass a battery of National Board Dental Examinations (NBDE) and a clinical dental licensing examination in order to begin practicing dentistry.

The Commission on Dental Accreditation (CODA) addresses the need for broad medical knowledge directly. Standard 2-11 clearly indicates that pre-clinical curriculum "*must* ensure an in-depth understanding of basic biological principles, consisting of a core of information on the fundamental structures, functions and interrelationships of the body systems" (2016). Standard 2-12 specifically emphasizes the oro-facial complex and its "complex biological interrelationship with the entire body" (CODA, 2016). A thorough knowledge of human structure is essential to meeting both of these standards.

PA programs are an average of 26.7 months in duration, with pre-clinical and clinical phases split fairly evenly (Physician Assistant Education Association, 2020). Designed to practice medicine under the supervision of a medical doctor, PAs were originally proposed as a means to better utilize a dwindling general practice medical doctor population in the 1960s (Asprey & Agar Barwick, 2017). The curriculum is an edited, condensed version of the traditional 4-year medical school curriculum. Due to the time constraints of PA programs, integration between pre-clinical and clinical phases is primarily confined to introducing clinical correlates in laboratory, case studies, projects, etc. Clinical rotations take place upon the completion of the pre-clinical phase. Ultimately, PA students must pass the Physician Assistant National Certifying Exam (PANCE) in order to be licensed as a medical provider in most states.

PA programs are evaluated for accreditation by the Accreditation Review Commission on Education for the Physician Assistant, Inc. (ARC-PA). The Accreditation Standards for Physician Assistant Education by the ARC-PA is somewhat more prescriptive in the curriculum standards, possibly due to the necessity of aligning curriculum to medical education. For example, Standard B2.02 (ARC-PA, 2018) states

> "The program curriculum *must* include instruction in the following areas of applied medical sciences and their application in clinical practice:
>
> a) anatomy
> b) physiology
> c) pathophysiology
> d) pharmacology and pharmacotherapeutics
> e) the genetic and molecular mechanisms of health and disease"

As noted in both dental and PA accreditation standards, anatomy is an essential component of the pre-clinical curriculum of HPE programs, and universities with multiple programs frequently combine students in courses with similarity in scope and sequence. At the University of Oklahoma Health Sciences Center (OUHSC), PA and dental students begin their programs together in a 6.5-week Clinical Anatomy course with cadaveric dissection. The Clinical Anatomy course provides core foundational knowledge of the human body through a clinical lens. Viewing anatomical knowledge through a clinical perspective allows students to begin thinking as a clinician would, and cadaveric dissection provides students with a 'first patient,' or the first place a future clinician can practice clinical reasoning (Ghosh, 2017). Of 66 clinical anatomy educators surveyed in 2016, all 66 reported utilizing cadaveric dissection for student learning (McBride & Drake, 2018). Considering how vital cadaveric dissection is perceived to be to develop clinical reasoning, Clinical Anatomy was delivered as a face-to-face (F2F) class until the spring of 2020.

The COVID-19 pandemic forced academic institutions fully online in March of 2020. Faculty worldwide adapted to complete spring semesters remotely while anticipating remote learning for the summer. At OUHSC, anatomy faculty began preparing the Clinical Anatomy curriculum for remote delivery for the newly matriculating class of dental and PA students.

Remote learning is an emergent solution to an educational crisis. Also called emergency remote teaching, remote learning is frequently confused with online learning, which typically takes 9 months to 2 years to plan. Remote learning occurs when educators have to move F2F pedagogy fully online within a small window of time (Hodges et al., 2020). Materials may be slightly modified to accommodate the new delivery platform, but the majority of the curriculum, including content and assessment, remains essentially unchanged. An example of remote learning is uploading previously recorded lectures online for students to watch. Planned online educational materials follow best practices, such as breaking up a lecture into 5-10 minute videos with active engagement throughout or gearing assessment toward group projects and open exams (Reyna, 2020).

Anatomy educators are familiar with online learning as a response to research advocating for more active learning opportunities (Abeysekera & Dawson, 2015; Day, 2018; Entezari & Javdan, 2016). Frequently termed flipped classrooms or blended learning, moving some or all of the lecture component of a class online allows medical educators to maintain the required content of a course while simultaneously providing space in the schedule for problem-, team-, or case-based learning. In the didactic phase of health professions education, active learning is used primarily to introduce clinical correlates and promote problem-solving skills that students will need upon entering the clinical component of their education (Drake, 2014).

Fully online anatomy programs exist for undergraduates (Attardi et al., 2016, 2018), post-graduate certifications (Kelsey et al., 2020), and pharmacy students (Limpach et al., 2008). As previously noted, anatomy educators of clinical programs, however, strongly prefer an in-person dissection laboratory for deeper learning (McBride & Drake, 2018). While some international clinical programs do not engage students with cadaveric dissection (Longhurst et al., 2020;

Pather et al., 2020), the majority of clinical programs prefer to maintain as many cadaveric dissection laboratory hours as possible due to the variety and depth of clinical skill building (Rizzolo & Stewart, 2006), and non-traditional discipline independent skill development (D. J. R. Evans et al., 2020) that dissection provides.

The Clinical Anatomy course for PA and dental students at OUHSC prior to 2020 was a 6.5-week time-intensive course arranged in a traditional lecture/cadaveric dissection laboratory format. Weekly spotter examinations in the laboratory provided formative feedback, and for this course 'formative' is defined as low-stakes assessments. Each two-week unit culminated in a summative multiple-choice assessment favoring clinical vignette-style questions, similar in style to certification exams. Second year medical students volunteered to be teaching assistants (TA) during the 2-hour laboratory periods (4X/week), providing immediate feedback and dissection assistance as necessary. The TAs were also available for extra tutoring upon request. With the onset of COVID-19, OUHSC anatomy faculty endeavored to convert this course to a fully remote format that recognizes the call by Jones (2020) to consider the ethical necessity of holding remote learners to the same academic standards while acknowledging (and mitigating when possible) the impact of a pandemic on student learning.

Due to the ethical issues and time constraints, it was decided to offer the online course in as similar a manner to the F2F course as possible. As such, both lecture and laboratory experiences were delivered synchronously. This changed the format of the lectures very little as they were already delivered as PowerPoint™ (Microsoft, Inc.) presentations with 1-3 audience response system (ARS) questions embedded to facilitate student discussion. The lectures were recorded and uploaded daily so that students could review the material as necessary. Students received formative points for answering ARS questions correctly, so while attendance was not required per se, students regularly attended lecture in order to accrue points. Uploading daily lecture recordings and ARS points were consistent with previous F2F courses. Students were allowed to have their cameras turned off for lecture and remained muted unless they had a question.

Moving a 3-dimensional, tactile, immersive laboratory experience online was significantly more challenging. Ultimately, faculty created 58 custom dissection videos of approximately 2 to 15 minutes in length for students to view, essentially creating a "guided and curated journey" through material that is traditionally taught in 3-dimensions in an exploratory manner (D. J. R. Evans et al., 2020) The videos were linked to the learner management system. Three cadaveric specimens were used to create these videos (2 males, 1 female). During these videos, faculty briefly demonstrated dissection approach, pointed out anatomical structures, and discussed common misconceptions or variations. Faculty advised students to watch the lab videos prior to synchronous laboratory review sessions the next day and to bring questions.

Laboratory review sessions were constructed to mimic the laboratory as much as possible. Students were divided into 4 groups and sent to pre-assigned breakout rooms within the video conference, and TAs populated the rooms each day. Teaching assistants originally signed up to assist with dissection but stayed on to tutor remotely. The TAs were allowed to sign up for what subject/days they wanted to lead. In addition to teaching assistants, each room would have one faculty member observing the session, and faculty rotated rooms daily to ensure equal student access. Faculty were available for questions if teaching assistants did not feel comfortable in answering, similar to how 1-2 TAs would be placed at each cadaver and faculty would float around the laboratory to provide feedback or explore a clinical correlation. Faculty advised TAs to prepare for laboratory sessions by taking screenshots from the videos (or

PowerPoints™ (Microsoft, Inc.)) and asking students to name structures. TAs might also have small review lectures prepared depending on the difficulty of the topic. Besides exchanging dissection for videos and discussion, the laboratory review sessions differed from F2F laboratory in that there were typically 4-6 students dissecting at a tank at one time, while there could be up to 25 people in a lab review session. Unlike dissection, lab review sessions were not mandatory but were well attended. Though admittedly not ideal, faculty concluded that the remotely learned content was as similar to the F2F content as possible.

Significance of the Problem

Acknowledging that dissection (or any laboratory) could not happen for students beginning clinical programs in the Summer of 2020, anatomy educators worldwide began calling for elucidating and evaluating institutional changes to accommodate remote learning (Gibbs, 2020; Gordon et al., 2020; Reyna, 2020). Specifically, requests to map sustainable and equitable pedagogical courses of action (Jones, 2020) that focus on temporary solutions [with the possibility of incorporating positive actions in future courses (Pather et al., 2020)], highlighted a need for research that indicates best practices in online anatomy education as educators proceed through this pandemic. In a qualitative analysis of a webinar to support anatomy educators at the onset of the pandemic, Cleland and colleagues (2020) noted a request for "all colleagues to record and evaluate their educational innovations, given that 'their actions will probably shape the future of health professions' education and training forever and in doing so, could just lead to real transformative and transformational learning for all of us.'" Anatomy educators are experiencing a seismic shift of how clinical anatomy is taught to students. Research such as the current proposal could be synthesized with other evaluations of innovations to determine a best path forward through emergency pandemic clinical anatomy education and beyond.

Research Purpose

The central aim of this study is to add to the scant knowledge base of emergency remote teaching of Clinical Anatomy during a pandemic. Specifically, one purpose is to determine if formative and summative academic outcomes differ between F2F and remote delivery of Clinical Anatomy. This is actually a well-documented question in academia generally (M. G. Moore & Diehl, William C., 2019), but little documentation exists for laboratory-based clinical anatomy professional courses. A second purpose is to determine student perceptions of anatomical knowledge. This purpose emerged from a student focus group and indicated their concerns regarding lack of dissection during the remote Clinical Anatomy course. The final purpose is to relate how students perceive their anatomical knowledge to their academic outcomes. Students were asked to begin a difficult course of study remotely with a novel laboratory delivery format during a pandemic. Comparing the academic outcomes of a pre-pandemic F2F course to those with remote delivery while providing the context of student perceptions potentially provides insight into the unique pandemic-altered student experience.

Research Questions

1a. Do clinical anatomy academic outcomes of PA and dental students differ between remote and face-to-face learners?

1b. If so, how do the academic outcomes differ?

2. How do PA and dental students perceive their anatomical knowledge upon completion of a remote, synchronous Clinical Anatomy course?

3. To what extent do PA and dental student perceptions of anatomical knowledge relate to their academic outcomes?

The following chapter provides an overview of literature that will situate Clinical Anatomy within the history of medical education, detail the theory of distance education, and discuss the current research of blended and fully online learning.

Chapter 2: Literature Review

Due to the reduction of Clinical Anatomy contact hours, the increase in demand for active learning techniques and self-directed learning strategies, one avenue of medical education research has focused on online learning. The following review of literature will provide a history of pre-clinical medical education, the major theories of distance education, and an overview of online learning. Additionally, a discussion of early COVID-19 era medical education literature will conclude the chapter.

The curricula of American medical and dental education have undergone a radical transformation in the past 250 years. Medical training in the 17th century was an extended apprenticeship with little to no guidance on required competencies or uniform mechanisms to assess fitness to practice medicine. Originally a response to widespread poor clinical practices, curricular reform evolved into an evidence-based, systematic process that incorporated the functional portions of a previous movement into a new program and philosophy. Specifically, the past 60 years of curricular reformation focused on aligning medical and dental curricula to concurrent cognitive science research.

Curriculum has multiple meanings, and for this study is defined as a program of teaching and learning which takes place in a formal setting and contains four dimensions: aims, content, methods, and assessment (Scott, 2001). The aims of American medical and dental curricula ultimately coalesced, with a recent Harvard University report serving as example: promote critical thinking utilizing expert comprehensive knowledge frameworks. Additionally, Harvard educators aimed to construct curricula that promoted professionalism and self-directed, lifelong learning (Schwartzstein et al., 2020). Hypothetico-deductive reasoning, or critical thinking based on the scientific method, could only be applied within broad knowledge of the basic sciences.

Basic sciences are the language of medicine as they are the fundamentals of understanding pathophysiology and the reasoning of drug selection (Ganguly et al., 2019).

Anatomy education in the health professions has been subject to scrutiny and change during the past thirty years for multiple reasons. Anatomy is a basic science traditionally taught by lecture and dissection laboratory in the didactic, or pre-clinical phase of a program. Introductory clinical skills and reasoning were integrated into anatomy curriculum over the past 35 years to promote the critical thinking capabilities of students progressing onto the clinical phase (Cooke et al., 2010). Additionally, medical knowledge is projected to double every 73 days by 2020 (Densen, 2011). Integration and exponential growth of medical knowledge prompted administrators nationwide to cut the number of contact hours devoted to gross anatomy in favor of seemingly more relevant content (Drake et al., 2009; McBride & Drake, 2018). More recently, research promoting constructivist learning methods permeated medical education, prompting an evaluation of the didactic years' teaching methodologies (Cooke et al., 2010). Acknowledging the impossibility of teaching the volume of knowledge available to students, accrediting bodies such as the Accreditation Review Commission on Education for the Physician Assistant (ARC-PA, 2018) and the Commission on Dental Accreditation (CODA, 2016) included directives for the development of self-directed and self-regulated learning (SDL, SRL) skills for life-long learning.

Online learning is one strategy that anatomy educators utilized to resolve these time constraints and pedagogical challenges. Online learning has multiple definitions but can generally be defined as a learning method taking place in geographically separate areas and/or time via technology (J. L.Moore et al., 2011). This literature review begins with a summarization of the history of medical and dental curriculum reforms. Generally, medical education curriculum reforms *are* dental education curriculum reforms (Kassebaum & Tedesco, 2017; Lantz & Shuler, 2017; Pyle, 2012). As such, dental curriculum reform deviations are noted within the framework established by medical curriculum reform in this review. Subsequently, the literature review defines and discusses the theoretical framework of online learning, expands the rationale for utilizing online learning strategies, reviews the research in online anatomy education, and concludes with a discussion of the necessity of emergency remote teaching (ERT) research to guide anatomy educators on how to adjust their curriculum to reflect the best practices of online education.

History of American medical and dental education. Colonial American health professions education varied considerably. Though 2 universities with medical schools existed in 1765, the majority of medical students apprenticed to a local physician, attended a proprietary school, or self-studied and began practicing medicine (Flexner, 1910). Dentistry was considered a trade due to the mechanical aspects of tooth repair, thus apprenticeship was the only option until proprietary dental schools opened (Santangelo, 1981). Many dentists of the time received no training, and quackery within both dentistry and medicine were common occurrences. No schooling was accredited, and no physicians or dentists were assessed for licensure. As a result, little incentive existed to attend a university (Papa & Harasym, 1999). Within this setting, curriculum reform began as a response to disparities in medical training.

Apprenticeship-based model, 1765 onward. The apprenticeship-based curriculum model hybridized the concepts of university and apprenticeship into a mostly proprietary system of classroom education followed by practical application. Basic science knowledge was considered irrelevant to the practice of medicine; thus the model began with clinical lectures delivered in two repeating, 4-month semesters. Anatomy, physiology, and other sciences were included in these lectures through the narrow scope of clinical application. Upon completing the identical semesters, students apprenticed under a practicing physician for 1-3 years (Papa & Harasym, 1999). Though the ideal master-apprentice relationship generated an exceptional learning experience, the quality of the training depended largely on the depth of the mentor's experiences and aptitude, and the process remained neither accredited nor standardized. The lack of regulation also meant that students had no impetus to attend a school instead of apprenticing with a local doctor.

Dentists, apprenticeship-trained or self-taught, first gained the opportunity of formal dental education in 1840 when the Baltimore College of Dental Surgery opened. There were four proprietary dental schools by 1865. The initial slow growth of dental schools was attributed to resistance to forgo apprenticeships for a costlier alternative, though by 1900 there were 57 institutions (Institute of Medicine, 1995). The dental school curriculum, though not uniform, was entirely clinical as tradesmen were not thought to be in need of basic science education. Ultimately, dentistry would have to overcome its 'trade' reputation in order to be considered a profession (Gies, 1926).

By the 1850s, textbooks and a primitive American Medical Association served to provide the genesis of standardization of content knowledge and medical education programming, respectively, but the apprenticeship-based curriculum model still promoted extreme variations in the quality of training received by students (Custers & Cate, 2018). Similarly, a fledgling American Dental Association was organized in 1861 to promote the regulation and professional stature of dentistry (Santangelo, 1981). Even with organizational supports, the most significant drawback of the apprentice-ship based model was the lack of clinical competency assessment of new graduates (Papa & Harasym, 1999). The extreme variations in training, lack of basic science education, and lack of assessment led leaders of both the medical and dental professions to call for significant adjustments to be made to American medical and dental education.

Discipline-based model, 1871 onward. The apprenticeship-based model had severe limitations. Several schools in America looked to European models of medical education, with Johns Hopkins emerging as an early adopter. Medical schools adopting the discipline-based model were typically housed within universities already, and basic science disciplines such as anatomy and chemistry were added to clinical application coursework. Most medical schools, however, did not fully make the shift toward the new model until the release of the Flexner Report in 1910 (Cooke et al., 2006).

The Flexner Report was the result of a comprehensive research study of American medical schools commissioned by the Carnegie Foundation. The American Medical Association, concerned about the poor quality of physicians graduating from unregulated medical schools, approached the Carnegie Foundation for the Advancement of Teaching to survey medical education institutions and develop recommendations based on the evidence (Drake, 2014). Flexner, a rigorous social scientist, validated much of the European model, and made several recommendations for both program structuring and curriculum content. Flexner recommended medical education institutions should pursue university affiliation and curriculum expansion to include basic science. With the expanded volume of knowledge, Flexner advocated a standard timeline of two years of basic science followed by two years of clinical application (Flexner, 1910). Additionally, he established the model of using data to drive curriculum reform.

Dental professionals, having witnessed the profound changes in medical education instituted as a result of the Flexner Report, asked the Carnegie Foundation to commission a report for dental education. The Gies Report catalogued similar findings to the Flexner Report, including the need for research, teaching, and service to function collaboratively for student progress, university affiliation, and a standardization of curriculum (Gies, 1926). Though the decline of proprietary schools was well underway, Gies articulated various steps universities should take to elevate dental education on par with medical education and included similar prerequisite and basic science coursework and research faculty (Institute of Medicine, 1995). Premier dentists of the era had long been advocating for the addition of the basic sciences due to their understanding of the relationship between the oral cavity and the body. Additionally, a 4-year curriculum was established, enabling dental faculty to include the same basic coursework as presented by medical faculty (Santangelo, 1981). As a result of the Gies Report and other professional recommendations, a discipline-based basic science curriculum similar to medical education was then required of dental students (Pyle, 2012).

One of the positive features of the expanded curriculum of the discipline-based model was the synergy derived from placing basic scientists and clinicians within the same programs. Clinical practice and research, encouraged by Flexner, emerged as a standard feature of the discipline-based model (Hecker & Violato, 2008). Additionally, new teaching methods were developed, with critical thinking and what would come to be called self-regulated learning emerging as essential program objectives. The focus of medical education shifted from memorizing clinical knowledge to the development of hypothetico-deductive reasoning and autonomous, active learning in an information rich environment (Papa & Harasym, 1999; Santangelo, 1981).

Though the discipline-based model improved the depth of knowledge and cultivated professional habits of mind, there were limitations. With the strict separation of basic science and clinical application, students had to independently apply basic science information during the clinical years (Papa & Harasym, 1999). The assumption that teaching hypothetico-deductive reasoning in the basic sciences would translate to correct clinical reasoning was inaccurate and frustrated both students and faculty. Another issue was the lack of coordination and communication between departments. Combined with a lack of program learning objectives, this led to an absence of scope and sequence of topics within the curriculum (Ganguly et al., 2019). Ultimately, this put undue cognitive stress on students to apply forgotten information or to apply information in ways students had never practiced. Acknowledgement of these limitations led educators to propose a new model utilizing a concept still researched today: integration.

Organ-system-based model, 1951 onward. Frustrated with the irrelevance of pre-clinical basic science minutiae being taught by departments, educators sought to rearrange and restructure basic science information so that its relevance could be immediately observed by students. By rearranging the curriculum by organ-system, educators integrated anatomy, chemistry, etc. for each organ-system (Ganguly et al., 2019). Medical educators were hoping that integrating the basic science content together anatomically would translate into better diagnosing skills in the clinical years (Hopkins et al., 2015).

The organ-system-based model and its emphasis on integration initiated further institutional change: curriculum committees began to control the educational content rather than individual departments. Department representatives met to determine the most salient basic science information to be learned for each organ-system. Improved coordination and communication between departments did reduce redundancy, but problem solving/diagnosing in the clinical years remained a struggle for students (Ganguly et al., 2019). Curriculum committees responded by adding independent self-regulated learning modules of basic science content during the clinical years of schooling. Due to the self-study aspect of this second iteration of integration, learning objectives were introduced for the first time (Papa & Harasym, 1999).

Dental schools that shared faculty and resources with medical schools may have experienced the shift to the organ-systems-based model, but the model was not identified amongst professional organizations or reports as a necessary curricular change. The literature mainly mentions student dissatisfaction with 'disconnected' basic sciences from 'traditional' (discipline-based) models and the need for adoption of integration and problem-based learning. (Institute of Medicine, 1995; Pyle, 2012; Santangelo, 1981). Dental schools in the 1940s and 1950s largely focused on research and scientific advancement, and incorporating general physical health and public health into the curriculum (Pyle, 2012; Santangelo, 1981).

While the organ-system-based model of medical education effectively streamlined curriculum, the model did not serve to improve problem-solving skills in the clinical years. Integrating content, whether within the basic sciences or the addition of basic science review within the clinical years, did not equate to retention and correct application of the knowledge in a practical situation (Papa & Harasym, 1999). Both the model and integration have evolved since then, and the organization of content according to organ-systems remains a popular approach within medical education (Hecker & Violato, 2008). Effective integration methods are still a major topic of medical education research and the impetus of the remaining models (Hopkins et al., 2015; Schwartzstein et al., 2020).

Problem-based learning model, 1971 onward. The failure of the organ-based-system model to transfer hypothetico-deductive reasoning skills from the basic sciences to clinical application prompted the development of the problem-based learning model. The problem-based learning model integrates basic science information in a clinical reasoning scenario with the goal of transferring the reasoning schemata to clinical application later in the program (Hecker & Violato, 2008). Cognitive science was a burgeoning research field in the 1960s and 1970s, and one key outcome was the necessity of context for retention (National Research Council, 2000). By providing basic science information with case studies, for example, students perceived how basic science information was necessary to diagnose a patient. By having students work through problems, students generated the classification and categorization outlines, or schemata, necessary to successfully diagnose patients in the clinical years of their education (Hecker & Violato, 2008).

Dental faculty particularly appreciated the context that problem-based learning provided to dental students in the pre-clinical years. As early as 1955, students complained about the uselessness of the basic science curriculum, declaring their impatience about having to wait to get to the material 'that mattered' (Institute of Medicine, 1995). In this instance, dental schools were the early adopters of the problem-based model, incorporating clinical cases and problems into their basic sciences before the model became widely utilized in medical schools (Lantz & Shuler, 2017). This shift in emphasis from disciplines to active problem-solving also demonstrated the dental profession's commitment to improving hypothetico-deductive reasoning skills and promoting self-directed learning (Kassebaum & Tedesco, 2017).

The cognitive research literature promoted students as active learners and more self-directing participants; however, exposure to clinically oriented problems did not create the proper schemata for differential diagnosis in a clinical setting. Students used case-specific knowledge to solve cases rather than an overarching schemata. For example, hypertension has multiple causes, and a case study usually presents one origin of a symptom. Unless students were exposed to all of the causes of hypertension, they would use the case-specific information rather than the entire classification system of hypertension to diagnose. Experts, however, use the schemata associated with symptomology to consider all possible outcomes. By narrowing the focus too far initially, students exclude potential solutions. Ultimately, medical educators recognized an insufficient hypothetico-deductive reasoning skills in their clinical students due to an incomplete schemata (Papa & Harasym, 1999).

Clinical Presentation Curriculum Model, 1991 onward. With the evidence that medical students were not building or transferring adequate schemata, medical educators at the University of Calgary devised a curriculum that incorporated the functional concepts of cognitive research with medical content knowledge from a different perspective. Rather than present problems, organ-systems, or disciplines, educators began presenting symptoms, or the clinical presentation, first. Educators also presented students with the schemata, called decision trees, that experts work through in order to obtain a proper diagnosis (Ganguly et al., 2019). Terminal (competency) and enabling (basic science) objectives, in conjunction with decision trees, delimited and scaffolded information (Hecker & Violato, 2008). Basic science served to explain the anatomy, physiological mechanisms, etc. for each potential cause of a symptom (Ganguly et al., 2019). Essentially serving to make expert thought processes explicit, the clinical presentation model's primary advantage is that the schemata for each symptom had already been taught; students did not need to restructure their basic science knowledge in their clinical years (Papa & Harasym, 1999).

Curriculum in modern medical and dental education. In reality, few schools strictly adopt one curricular model. Most schools operate as a hybrid, with components of each curricular model blended into a cohesive program. Competency-based medical education draws from the reconceptualization of curriculum as terminal performance objectives in the clinical presentation model but may utilize organ-systems-based models for the basic science years (Ganguly et al., 2019). Undergraduate medical education still follows the four-year pattern of two basic science years plus two clinical science years founded in the disciplined-based model (Flexner, 1910). Integration, originating in the organ-systems-based model, is present in the majority of medical and dental education programs. Only 2% of dental schools reported no integration in a 2015 survey administered by the American Dental Association (American Dental Association, 2016). In a survey of clinical anatomy educators, 94% of respondents indicated their course was part of a partially or fully integrated medical curriculum (McBride & Drake, 2018). Other concepts, such as community-based education in dentistry, were emphasized as a practical expansion of integration/problem-based learning (Kassebaum & Tedesco, 2017). Other schools begin discipline-based for 1 year, then restructure to an organ-systems-based model for the second year. Even the apprenticeship-based model, for all of its faults, is revisited in concept as a "cognitive apprenticeship," or making tacit information explicit within an authentic learning experience, visualized in the expert schemata (decision trees) of the clinical presentation model (Anstey, 2017).

Active learning encompasses a broad range of learner-centered, problem-based curricula, originally conceptualized in the problem-based model and remains a key feature of integrating clinical experiences within the basic sciences regardless of program curriculum model (Lantz & Shuler, 2017; Wijnen-Meijer et al., 2020). Similarly, integrating basic sciences within the clinical years frequently employs a spiral design of revisiting a topic for just-in-time teaching prior to a clinical experience. Both integration concepts are frequent topics of medical education research (Brauer & Ferguson, 2015; Lantz & Shuler, 2017).

The University of Oklahoma Health Sciences Center follows a modified organ-systems-based curricular structure. Clinical anatomy is offered first for dental and PA students as an introductory course before the rotation of organ-systems coursework begins. This provides students with the basic vocabulary and introductory clinical skills to be successful. Active learning such as PBL is incorporated to promote integration between the pre-clinical and clinical program components. For the clinical anatomy course at the University of Oklahoma Health Sciences Center, active learning took place during cadaveric dissection until the summer of 2020. Cadaveric dissection was replaced with an online flipped laboratory to ensure the safety of faculty and students during the 2020-2021 COVID-19 pandemic. The following sections explain the theory and rationale of utilizing online learning.

Definitions and theoretical framework of online learning. Distance education is defined as instructional methods in which teaching and learning take place in geographically separate areas through a communication medium (Moore, 2019). Historically, the communication medium was written correspondence, video, or radio, but the most common medium today is some type of online communication from a web-enabled electronic device. Combining the concept of distance education with modern technology gives rise to online learning, defined previously (Chapter 1).

Two common ways to describe online learning is by temporality and the amount of the course that is conducted online. Temporality refers to whether or not teacher and student (or student and student) interactions are conducted in real time (Singh & Thurman, 2019). Courses (or portions of a course) conducted in real time are considered synchronous. Asynchronous courses (or portions of a course) maintain interactions through discussion boards, email, or other forms of delayed correspondence. Courses that are completely online are frequently described as “fully” online (Taylor et al., 2020), and partially online courses are commonly called blended learning courses (Ngan et al., 2018). The percentage of the course conducted online varies widely, but any course that has an online component is considered blended learning.

Online coursework conducted as a temporary shift of instructional delivery due to a crisis is called emergency remote teaching (ERT) (Rapanta et al., 2020). Emergency remote teaching differs from online learning in that curriculum planning for ERT consists of moving materials created for face-to-face (F2F) coursework to an online presentation rather than the more rigorous creating or curating materials for the online classroom specifically. Additionally, online courses are typically planned 9 months to two years in advance, whereas ERT situations usually have 2 months or less to prepare (Hodges et al., 2020). Educators that experience ERT do not have the opportunity to optimize their curricula for minimal transactional distance (Moore, 2019).

Moore’s Theory of Transactional Distance provides a theoretical framework for online course design. ‘Transaction’ encompasses the relationship between the behaviors of teachers and learners in which they are geographically separated and have to communicate through a technology (Simonson et al., 2011). The separation necessitates patterns of behavior regarding course organization and communication between instructors and students. The goal, according to Moore, is to use the course organization and communication patterns to bridge a psychological distance, or a distance or gap in the student’s understanding (2019). Students participate in this relationship by exercising autonomy, or making personal decisions about what, how, and how much to learn.

Course organization, or structure, influences both dialogue and student autonomy. Structure can be highly flexible, such as a discussion-based course with a co-constructed syllabus. More rigid structures of course organization allow less student input, and these courses are less responsive to student input regarding educational objectives, teaching strategies, or assessment (Moore, 2019). Clinical Anatomy, similar to other medical education didactic coursework, tend to be more rigid in program structure due to external competencies and standards required to practice the profession. According to Moore, transactional distance is increased in this type of class.

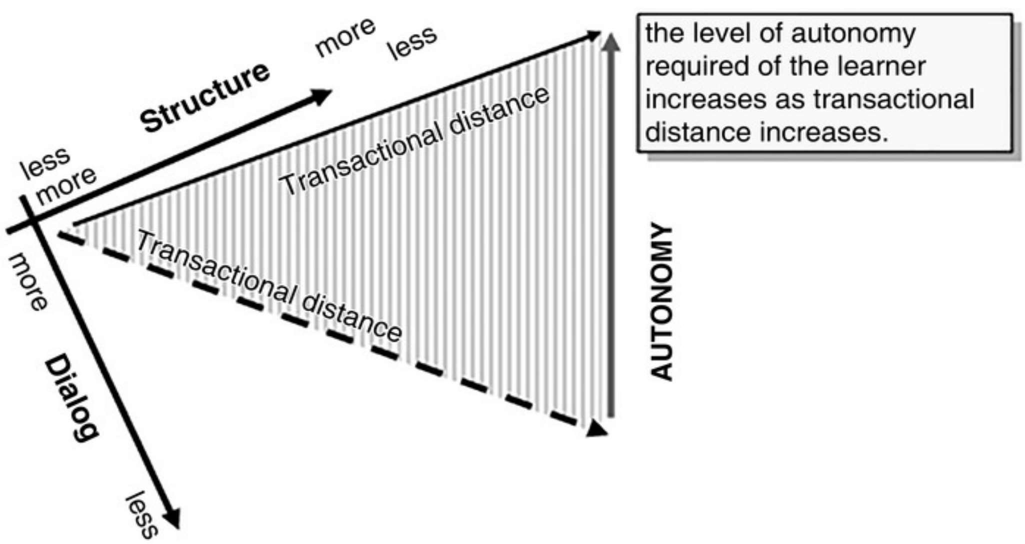
Dialogue is a synergistic, constructive interaction between teachers and students. Active listening and mutual contributions are the hallmarks of a highly dialogic classroom (Moore, 2019). Dialogue depends on a number of factors (like class size), but the structure of the course is the primary determinant. Courses designed for students to listen, watch, or read without opportunity for discussion is an example of the course structure dictating the dialogue. Transactional distance increases with decreased dialogue.

The key to successful online education is aligning the structure and dialogue of the course with overarching educational objectives that may guide learner autonomy. As transactional distance increases, learner autonomy needs increase as well. A misalignment of structure, dialogue, or autonomy results in a suboptimal experience for students (Peters, 1998).

Moore refers to three interactions affecting dialogue and structure: learner-content, learner-instructor, and learner-learner (Moore, 1989). Educators create presentations, activities, and assessments to facilitate interactions between the learner and the content. Moore especially invites scrutiny of this interaction in distance education at the point where students are trying to apply information for the first time, stating they are particularly vulnerable to misapplication or misconception without proper scaffolding (2019). Simonson affirms the significance of learners not merely receiving the material but interacting with it for improved retention (2019). Learner instructor interactions should serve to provide opportunities for students to engage with instructors, sometimes about content or student autonomy support, but also by modeling appropriate behaviors. Learner-learner interactions are more age dependent; however, regardless of age, a community of inquiry suited to the needs of students promotes engagement and motivation (Fiock, 2020; Reyna, 2020).

Figure 1.

Model of Theory of Transactional Distance



Rationale for online learning in anatomy education. A clinician must be able to obtain, integrate, and interpret multiple sources of information to diagnose a patient: patient history, physical exam, lab work, imaging, patient files, additional health care team members, etc. Students in the health professions practice these skills under supervision during the clinical phase of their program. Utilizing a problem-based or clinical model during the didactic phase of education improved health education by providing authentic learning experiences for newer students (Pawlina & Drake, 2016) and early exposure to clinical reasoning and skills (Cooke et al., 2010).

In applying the problem-based or clinical model to anatomy education, educators were implementing a more constructivist philosophy toward education. Constructivism is the view that knowledge is created through human interpretation of experiences. Reality is therefore subjective (Crotty, 2015). Incorporating problem-based learning represents an epistemologic paradigm shift. Basic science research is firmly rooted in objectivism; additionally, western medicine is predicated on evidence-based practices. Objectivists maintain that an external reality exists, and only information obtained from carefully controlled observation (preferably experimentation) is valid (Hiller, 2016). With the adoption of problem-based learning pedagogy, anatomy educators had to shift their focus from what educators teach to what students learn (Drake, 2014; McBride & Drake, 2018). The adoption of learner-centered philosophies and methods within medical education is referred to as active learning.

The exponential increase in medical knowledge forces administrators and educators to continually evaluate the curriculum for relevance. The combination of increased knowledge with the movement to incorporate as much clinical reasoning and skills as possible resulted in a reduction of hours devoted to anatomy. Between 2002 and 2018, national gross anatomy contact hours dropped from averages of 196 to 127 hours (Drake et al., 2009; McBride & Drake, 2018). The decline in anatomy contact hours demonstrates an inverse relationship to the estimated doubling time of medical knowledge:

> It is estimated that the doubling time of medical knowledge in 1950 was 50 years; in 1980, 7 years; and in 2010, 3.5 years. In 2020 it is projected to be 0.2 years—just 73 days. (Densen, 2011)

Acknowledging this doubling of knowledge also prompted the incorporation of explicit self-directed learning (SDL)/self-regulated learning (SRL) curriculum. SDL and SRL are similar in that they are both skill sets that help students define planning, execution, and monitoring/reflection of goals (Saks & Leijen, 2014). SRL is frequently practiced in the school environment as the educator assigns the task and evaluation parameters but allows students the opportunity to independently execute and monitor the progress toward task completion. SDL differs from SRL in that the student determines the task as well as maintains autonomy throughout the process. Learners engaged in SDL also determine their own evaluation methods (Knowles, 1975). The ARC-PA (2018) standards state that students should be able to demonstrate appropriate information seeking skills suitable for continuing education, and the American Dental Association (ADA, 2016), standards include a broader set of SDL skills more consistent with Knowles' definition of SDL. As a result of these factors, anatomy educators sought ways to maximize the amount of content provided to students in ways that honored the shift toward active learning, incorporated appropriate clinical reasoning and skills, acknowledged the reality of fewer contact hours, and provided SRL and SDL opportunities to promote life-long learning. In the past 20 years, online learning has been utilized and investigated as a means of meeting these needs.

Online anatomy education. Traditional gross anatomy consisted of in-person lecture and laboratory. Students listened to content experts explain anatomy and its relevance to clinical practice in lecture, then proceed to lab to contextualize that information. As anatomy educators sought to improve student performance, learner-centered pedagogy became more prevalent (Aziz et al., 2002). As a result, modifying lecture content has been an enormous source of anatomy education research. Laboratory time, however, was already devoted to learner-centered, experiential learning and therefore less scrutinized (for curricular changes). A significant exception to this was research investigating fully online anatomy courses, where both lecture and lab content were moved completely online.

Any discussion of online learning in anatomy education research necessitates delineating overlapping research strands. Blended learning and flipped classrooms are two terms describing the same phenomenon: moving basic content online for independent study to prepare for active learning in class (Kellesarian, 2018). Flipped classroom and blended learning research diverges in purpose, however. Blended learning research typically evaluates the impact of what was moved online, while flipped classroom research typically evaluates the impact of what was added to the F2F classroom. Flipped classroom research that illuminated the significance of the online experience was considered for inclusion in this review. Additionally, a multitude of computer-assisted learning/instruction studies exist. A broader category than online learning, computer-assisted learning/instruction is any type of interactive learning on a computer and can include F2F activities ("computer-assisted learning," 2020). The absence of geographical distance would preclude a study of this topic from inclusion in this review. The rest of this chapter is a synthesis of how online learning was utilized in anatomy education in the literature, namely: blended learning, fully online learning, and emergency remote teaching.

Blended learning - module development. Many blended learning studies are evaluations of modules developed for online use. Modules are a prepared series of online materials for students to study independently. Module development frequently emerged as an observed student need, with student perceptions and usage data most commonly collected. Educators created a series of positively-reviewed online anatomy review tutorials for final year dental students prior to examinations (Durham et al., 2009). Similarly, Marker and colleagues adapted online digital images to create a series of annotated, interactive digital anatomy lectures for medical students (2010). Portions of the lectures were subsequently hyperlinked and utilized in F2F lectures as well as housed online for students to review independently. Student surveys indicated 87% were 'somewhat' or 'very' useful, and 63% asked for more of the interactive modules. (Marker et al., 2010).

Other studies measured flipping pre-clinical material that previous students considered difficult. Dental students serving as an historical cohort received an autonomic nervous system (ANS) lecture, while the following year students received a flipped online presentation and completed an active learning assignment/discussion in class. Both cohorts took a 10-question quiz to assess knowledge of the ANS. The flipped/blended cohort spent the same amount of planned time on the material, so time spent on materials was controlled as a variable, though researchers did not know if students in the flipped cohort spent additional time re-watching the flipped lecture or reviewed the material in other ways. Xiao and colleagues found the average quiz score to be higher for the flipped/blended vs. non-flipped course at 80% ± 19 vs. 69% ± 23 ($p < 0.01$), respectively (Xiao et al., 2018). Xiao's study indicated a flipped/blended pedagogy was more successful than a non-flipped course for difficult course material, and most students considered the modules to be useful.

Xiao's quiz contained 6 content questions and four case-based questions. When separated, the content quiz question results were significantly higher for the flipped/blended approach (83% ± 21) than for the non-flipped approach (73% ± 23) at a p-value of 0.05. Mean scores were not significantly different for the case-based questions. The gap in performance between the upper 27% and lower 27% of students significantly narrowed in the flipped/blended approach, with a 32.3% gap versus a 42.2% gap for the non-flipped cohort ($p < 0.01$) (Xiao et al., 2018). The improvement in content but not case-based questions is inconsistent with other studies indicating that flipped/blended learning improved learning of more difficult cognitive content but not lower levels (Day, 2018; Deshpande et al., 2020; Morton & Colbert-Getz, 2017). The improvement in score in the lower 27% is consistent with Day's results, however.

In a different study, faculty created a four-week flipped/blended curriculum module for PA students in anatomy. Students received online lectures that increased out-of-class preparation time by an average of 57.2 minutes. Students then attended class the next day to participate in CBL and discussion. The students indicated increased enjoyment, reduction of in-class boredom, and scored significantly higher on clinical vignette questions (94.1% versus 87.3%, $p = 0.019$) than a historical, lecture-based cohort that took the same exam. There was no statistically significant difference between cohorts on the non-clinical vignette exam questions (Deshpande et al., 2020). The significant results of the separation of test items by cognitive difficulty is complicated by the fact that the flipped/blended cohort spent more time with the material.

Pilot-testing a larger, planned curriculum change is another use of module development research. A pilot-test of 3 modules combining clinical vignettes, three-dimensional anatomy modules, and gamified quizzing were administered to undergraduate Pharmacy students in Hong

Kong prior to attending lecture. While 66% of students rated the software helpful to learning, no changes were observed in course grades, and average student GPA correlated to usage frequency data (r=.44) (Ngan et al., 2018). The Ngan study reveals issues common to online anatomy education research. The three micro-modules administered to students supplied an insufficient amount of knowledge to be detected by course grades, thus not matching data collection sensitivity to the magnitude of the treatment. The correlation between student GPA and usage frequency indicates a confounding issue. Did the students really learn more with a different pedagogy, or did they just spend more time with the information? Both issues will be encountered again when measuring the effects of blended learning.

Blended learning - academic outcomes. Blended learning is a popular method of online learning, hypothesized to suit anatomy education well due to the multimodal information delivery (R. A. Green & Whitburn, 2016). Green and Whitburn further describe how some modes of learning, such as 3-dimensional model rotation videos do not scale up well in a large lecture hall but work optimally when the student has control of the image and screen. Blended learning research as a whole has mixed results; this section begins with a review of positive outcomes, then negative or mixed outcomes, and concludes with studies investigating student perceptions or usage only.

In a large, rigorous meta-analysis designed to quantify the impact of online learning in education generally, comparing 50 cohorts of either blended or fully online student outcomes to their respective F2F cohorts resulted in a mean effect size of +0.2 $p < .001$ (Means et al., 2013). Interestingly, when blended and fully online cohorts were separated, the effect size for blended learning was found to be +.35 $p < .0001$, while the online cohort was not significantly different

+0.05, p = .46 (Means et al., 2013). Graduate and professional students comprised approximately half of the samples, with the health professions heavily represented. While not a review of online anatomy education specifically, the broad spectrum of students sampled from the 50 cohorts (representing 50 research studies of various disciplines) provides justification for inclusion in this review.

Specific to anatomy education, a three-year planned conversion from F2F to blended learning between 2013 and 2015 resulted in improved outcomes for second year physiotherapy students. The F2F (2013) average scores for lab practical exams (F = 37.26, p < .00) and the final exam (F = 10.86, p < .00) were significantly less than the average scores for the partially blended (2014) and completely blended (2015) courses (R. A. Green & Whitburn, 2016). The same statistics were applied to the course pre-requisite with no significant differences found between years, lending support that the findings were due to the course changes and not differences in student populations. Green does caution that students felt the workload in 2015 (completely blended) was high, though there is no basis of comparison for the comment (2016). Means et al. similarly cautions that learning conditions are not standardized when assessing most educational research (2013).

Another subset of studies sorted exam questions according to a modified Bloom's Taxonomy (Anderson & Krathwohl, 2001; Bloom, 1956). Multiple-choice questions were sorted into high and low categories, with 'high' representing apply and analyze, and 'low' representing remember and understand (Morton & Colbert-Getz, 2017; Day, 2018). Two years of first year medical students' exams from a Foundations of Medicine course, which included gross anatomy, were compared. When the 'high' Bloom's questions were resegregated back to apply and analyze, the 2014 flipped cohort scored 3% ($p = .30$, 95% CI -0.5% - 7%) higher for the 'analyze' Bloom's level questions than did the 2013 F2F cohort (Morton & Colbert-Getz, 2017). 'Low' Bloom's level questions were not significantly different between groups. Day had a similar outcome with students in a Doctor of Physical Therapy program; students from the flipped cohort earned a $76.7 \pm 15.4\%$ on 'high' Bloom's multiple-choice questions as opposed to $68.0 \pm 16.5\%$ from the traditional cohort Mann-Whitney $U = 4{,}076.5$, $p < 0.001$, $d = 0.55$) (2018). Morton argues that the active learning that ensues from flipping a classroom online ostensibly promotes deeper learning. Assessments reflecting deeper learning should therefore be used to assess efficacy (2016).

Day further identified positive results regarding low performers and long-term outcomes. Pre-matriculation student grade point averages (GPA) were sorted into quartiles. Students in the lowest two quartiles of the flipped cohort (GPA ranges 3.0-3.39 and 3.40-3.59) had significantly higher semester averages than the same quartiles from the traditional cohort (2018). A separate study investigating exam differences between a team-based/blended learning gross anatomy course and previous F2F courses did not find exam score differences (Nieder et al., 2005). However, significantly less variance in exam scores was found in the blended course, leading Nieder and colleagues to support the idea of lower performing students benefitting from a more active learning/blended learning format. For long-term outcomes, Day continued investigating student progress in the subsequent kinesiology course. Semester average scores were significantly higher for the formerly flipped anatomy cohort $88.5 \pm 4.6\%$ than for the traditional cohort $86.5 \pm 4.6\%$ (Mann-Whitney U, $p = 0.029$, $d = 0.37$) (2018). These data seem to support the findings that aligning program goals of deeper learning to appropriate assessment and indicates long-term retention advantages can be generated from a flipped classroom/blended learning format.

In a separate Bloom's test item analysis, researchers flipped/blended half of the lectures in a multi-modal pre-clinical anatomy course for first-year medical students and compared them to an historical cohort that did not flip/blend any lectures. They categorized 17 multiple-choice questions from the musculoskeletal unit exam common to both cohorts according to Bloom's Taxonomy (Anderson & Krathwohl, 2001; Bloom, 1956). Effect sizes for knowledge, apply, and analyze question responses were calculated at 0.43, 1.41, and 1.01 respectively, using Cohen's d test (El Sadik & Al Abdulmonem, 2020), potentially indicating a more significant effect in the higher Bloom's levels when at least a portion of lectures are flipped/blended.

In a second year undergraduate anatomy course, half of the course content was delivered online with custom videos, worksheets, and activities, with the other half delivered F2F. Students met for 2 hours a week for laboratory and 1 hour for further guided activities for the entire length of the course (White et al., 2019). Four practical exams were administered during the course, with each online and F2F unit equally represented. White found no statistically significant difference in scores but noted increased number of views correlated with increased scores $r^2 = 0.9174$; $p < .001$ (2019). These results correlate with other studies indicating student use of online content to revise knowledge (R. A. Green & Whitburn, 2016; S. M. Green et al., 2006).

Recent literature reviews yield mixed results. Chen et al. conducted a literature search of 82 articles, nine of which contained effect sizes ranging from $d = -0.27$ to 1.21, with a median of 0.08. The confidence intervals were inconsistent and included zero, suggesting a lack of flipped/classroom effectiveness over traditional teaching methods (Chen et al., 2017). Authors of a narrative literature review of the flipped classroom use in HPE reviewed 24 research articles between 2005 and 2017. Though the majority of studies (17) noted significant improvement in at least one academic outcome, overall the mixed results or lack of significant results prompted researchers to conclude a lack of conclusive evidence for adoption of the flipped classroom pedagogy (L. Evans et al., 2019). Authors did note, however, a lack of consistent terminology and poor quality of some of the included literature as limitations to their conclusions. A systematic meta-analysis of flipped classrooms that required pre-recorded videos prior to mandatory F2F meetings found an overall significant effect in favor of flipped classrooms for HPE (SMD = 0.33, 95% CI 0.21-0.46, $p < 0.001$), however (Hew & Lo, 2018). Perhaps a narrower review improved consistency of findings.

Remote versus F2F synchronous learning was studied in Pharmacy students participating in an anatomy/pharmacy calculations course. The purpose of this study was to determine if their unusual self-pacing curriculum would be effective in a remote location. Students self-pace learning through discrete learning modules and retest to competency (Fike et al., 2009). No statistically significant differences were obtained, which is consistent with media comparison studies overall: delivery method does not matter (M. G. Moore & Diehl, 2019, Means et al., 2013). However, this study had no laboratory component to consider. It is unknown whether a clinical anatomy course with a cadaveric dissection laboratory would have a similar outcome.

Blended learning - student perceptions. The remainder of this section is categorized by studies investigating student perceptions and usage of materials placed online: no academic outcomes were collected. A few of these studies included a broader perspective, thus including laboratory perceptions. These perspectives were included if deemed relevant to fully remote Clinical Anatomy learning.

In 2004, first year medical student educators realized that their radiologic anatomy pedagogy was outmoded by digital imaging techniques. Rather than having a preceptor standing at a light box holding up films, educators created blended learning modules that included pre-lab self-study cases, follow-up cases, and twice weekly F2F optional review sessions. All interactive modules were rated "useful" or "very useful," and the non-interactive module was modified and was rated "useful" in the following iteration (Shaffer & Small, 2004) indicating a preference for active learning.

Other studies served to reiterate commitments to cadaveric dissection. Similar in idea to Fleagle et al. (2018), pre-laboratory preparation and explanation for dissection was flipped to a blended learning format. Surveys of first year medical students revealed students felt more prepared for lab and had a higher quality experience when using the web-based preparation materials. Faculty noted improved efficiency (Granger et al., 2006).

Some students perceive laboratory time to be more valuable than other resources. When asked to rank resources from most to least useful, the largest percentage (29%) of nursing students in an anatomy and physiology course valued laboratory classes as most useful over reading the textbook, making notes, and engaging online materials (9%) (Barbagallo et al., 2020). Year 1 and year 2 medical students were surveyed as to their learning preferences in gross anatomy since the advent of e-learning (which in this case was some SRL online learning and other electronic materials). While students had generally favorable impressions of online materials, over 90% of students "agreed" or "strongly agreed" that "seeing specimens is essential to understanding" (Davis et al., 2014). Possibly as significant is the difference between Year 1 and Year 2 groups regarding how helpful e-learning was to them. Only 31% of Year 1 students used SRL e-learning materials, compared to 58% of Year 2 medical students (Davis et al., 2014). While admittedly this study barely qualifies as an evaluation of online learning, it does show how essential students thought cadaveric dissection was compared to all other forms of learning, including e-learning. The difference in use of e-learning materials between groups indicates competence or maturity may factor into the ability to self-regulate learning with online materials. Both of these points may become salient as the data of the proposed study is analyzed. Though Aziz et al. argued as early as 2002 that cadavers plus 'technology informatics' were optimal for learning anatomy, fully online anatomy courses are offered at many universities.

Fully online learning. Research of fully online anatomy for clinical programs is scant. In 2014, Drake published the results of a survey about the state of anatomy education, and fully online anatomy was not mentioned. In fact, only two of the 65 educators responded that dissection was not part of the student experience, indicating a commitment to at least some F2F teaching. In 2018, 100% of anatomy educators reported using cadavers for dissection, and 44% indicated that students had access to video dissections (McBride & Drake, 2018). Non-clinical anatomy programs, however, are responding to demand to learn anatomy online.

A post-graduate Anatomical Sciences degree was offered online beginning in 2015 to meet the demand for a time-flexible program that allowed for professional development and career development opportunities. Certificate and full diploma options are provided to meet that need. Most students (72%) were between the ages of 20-29 and female (Kelsey et al., 2020). The completely asynchronous program was delivered via online video, virtual lab and accompanying workbook, and formative quizzes. Discussion and wiki boards provided opportunities for student collaboration and staff support. Kelsey et al. acknowledged the challenge of providing sufficient materials for online laboratory, and students noted that the lack of physical specimens made learning more difficult (2020).

Creighton offered an online pharmacy program beginning in 2001. All courses were delivered synchronously, and anatomy was required in the first year. Anatomy laboratory was a required 2-week workshop the following summer, so while not technically fully online, there were so few graduate-level fully online courses it was included in this section. Students completed the same assessments as the F2F cohort, and the activities conducted in the classroom were modified to be completed on online discussion boards (Limpach et al., 2008). Students in the online cohort scored the same or slightly better than the F2F cohort in the four years studied, again indicating neither distance nor delivery affected the classroom experience. It should be noted that educators did not attempt to move their laboratory online, so a similar outcome is not unexpected. This anatomy course is similar to other fully online anatomy offerings that require an in-person visit to satisfy laboratory requirements, though most are at the undergraduate level.

Undergraduate online anatomy courses are more common than professional level coursework. Study.com offers a list of universities offering online programs (2020). Though some require visitation to the campus to satisfy an in-person laboratory requirement, many are fully online. The University of Western Ontario sought to offer fully online undergraduate anatomy to meet enrollment demands. Beginning in 2012, a small online cohort (n=20) and a F2F cohort (n=310) swapped content delivery for 1 week. Interviews were conducted to assess experiences, and the difficulty of using online 3D models was noted; students also preferred the interaction of F2F laboratory experiences (Attardi et al., 2016). In the following year, Attardi et al. revised the online offering to include laboratory groups that rotated through breakout rooms to work on 3D models with an instructor (2018). Student responses improved for both 3D modeling usage and interactions, and no significant differences were found in an analysis of exam scores or final grade (Attardi et al., 2018). Preventing student isolation and providing faculty support for lab facilitated student success. Attardi also noted the volume of fully online anatomy programs and the paucity of research in 2018.

Emergency remote teaching. Though instructional designers emphatically separate emergency remote teaching (ERT) from online learning (Hodges et al., 2020), it does occur online and will be included in this review. The literature regarding intersection of ERT and anatomy education thus far has been qualitative, editorial, or descriptive. Several review best practices for ERT (Cleland et al., 2020; D. J. R. Evans et al., 2020; Reyna, 2020; Taylor et al., 2020).

Others surveyed faculty in their region and shared what changes were made. Data from surveyed medical schools in the UK and the Republic of Ireland was organized into strengths, weaknesses, opportunities, and threats. Development on new online resources was noted by 71% of the respondents to be a strength, and 50% noted lack of practical sessions and cadaveric exposure to be a weakness (Longhurst et al., 2020). A survey of Australian and New Zealand anatomy educators revealed similar concern for loss of hands-on opportunities and anticipation for adapting information into new pedagogies (Pather et al., 2020).

Community development of both faculty and students was also considered. Cleland's qualitative analysis of a webinar of anatomy faculty sharing best practices indicated a need for support that was echoed in several other papers (Cleland et al., 2020; Gibbs, 2020; Jones, 2020; Pather et al., 2020). Jones posits several ethical commitments that need to be considered during ERT, not the least of which is a commitment to student well-being and equity (2020). This was described as not short-changing a student academically due to ERT while being responsive to the unusual stressors placed on students during a pandemic. Collectively, the literature on ERT to date is a supportive, asynchronous conversation between anatomy faculty worldwide designed to promote the best educational experience possible in an unprecedented time in history.

From emergency remote teaching to online anatomy education best practices. Cleland's call requesting educators to document and evaluate ERT acknowledged that crises such as a pandemic force innovation and transformation (2020). Anatomy educators worldwide will evaluate their ERT situations and consider what should be kept, modified, or discarded in the coming months and years. Clinical anatomy educators and students repeatedly indicated a strong preference for the cadaveric dissection laboratory experience throughout the review of online learning literature for anatomy. Most cadaveric dissection laboratories are similar to what was described in chapter 1 for F2F students at OUHSC: a small team of students working toward a common goal with expert (and/or near-peer) support available for immediate guidance and feedback. Analysis of dissection experience indicates a learner-centered, constructivist approach with scaffolding to support learner-content interaction, feedback to support learner-instructor interaction, and student teams to support student-student interaction (M. G. Moore, 1989).

Attardi (2018) and Kelsey (2020) demonstrated that non-clinical anatomy content can be successfully delivered online. The concern for clinical anatomy educators is if/how the loss of the physical specimen and the laboratory experience impacts student clinical reasoning and skills development. The distinction is that for the future clinician, all anatomical knowledge is filtered through a lens of clinical application. Clinical applications are featured in cadaveric dissection as each donor brings an open-ended experience and exploration to the laboratory. What's next for anatomy educators is to empirically determine what online pedagogical methods most closely fulfills both the needs for the three types of interactions as well as the needs for clinical reasoning and skills development.

The proposed study is an analysis of formative and summative exam scores and student perceptions regarding their anatomical knowledge. Summative exams will be assessed by separating clinical application and analysis anatomy questions from lower Bloom's level questions, similar to previously described research (Day, 2018; Morton & Colbert-Getz, 2017). Any future investigations of potential long-term effects of clinical anatomy ERT or changes made to convert from ERT to online learning need to be made with knowledge of how students performed academically and how they perceived their anatomical knowledge in the short term. This information may direct anatomy educators toward best practices in a new and unfamiliar pedagogy.

Though face-to-face instruction has been the norm for Clinical Anatomy, fully remote instruction was necessary for the 2020 course and should be evaluated for efficacy and equity. The following chapter will present the methods used to analyze actual and perceived anatomical knowledge and to determine any relationships between the data. Chapter Four will present the analysis and discussion of the data. The final chapter will present a discussion of conclusions, including implications for future educators, future research recommendations, and limitations.

Chapter 3: Materials and Methods

In this chapter, the theoretical framework, methodology, and research design will be discussed. A significant portion of the chapter will be devoted to describing the data collection and analysis. Both the statistical analysis of assessment items and the construction and administration of the student perspectives survey will be featured. Kane's Interpretive-Use Argument framework will provide the structure for a detailed justification of the methods and use of the data.

Emergency remote teaching (ERT) offers unique opportunities and challenges to educators. One opportunity is the investigation of best practices for online anatomy education. By determining what aspects of ERT were effective, researchers can begin to thoughtfully construct an online curriculum that fully meets student needs in the event moving fully online becomes necessary or desired in the future. Additionally, effective aspects of ERT might be considered for inclusion in face-to-face F2F coursework where appropriate.

A central aim of this study was to determine if physician assistant (PA) and dental students' academic outcomes differed between remote and F2F learners. A necessary early step in determining effective pedagogical practice is assessing student learning. A second aim was to determine students' perceptions of their anatomical knowledge. Determining how students felt about their learning may offer context for the academic outcomes and help educators acclimate students to fully online learning in the future. The concluding aim was to document to what extent the students' perceptions related to their academic outcomes. The research proposed in this study addresses the following questions:

1a. Do Clinical Anatomy academic outcomes of PA and dental students differ between remote and face-to-face learners?
1b. If so, how do the academic outcomes differ?

2. How do PA and dental students perceive their anatomical knowledge upon completion of a remote, synchronous Clinical Anatomy course?

3. To what extent do PA and dental student perceptions of anatomical knowledge relate to their academic outcomes?

This study has two components: a statistical analysis of summative and formative exam scores comparing F2F and remote student cohorts, and a compilation of survey data regarding perceptions of anatomical knowledge obtained from the remote student cohort.

Beginning with situating the study within a theoretical framework, the discussion continues with an explanation of research design, participants, data collection, and data analysis.

Theoretical Framework

Post-positivism is frequently described as a rejection of positivism. Both dictate that an objective, external reality exists outside of human interpretation, but positivism as a research paradigm dictates that only what can be objectively measured qualifies as reality (Crotty, 2015). Positivism historically was a rejection of metaphysical attempts such as alchemy to obtain knowledge; strict adherence to the scientific method was the only way to remove bias and obtain empirical, repeatable, verifiable knowledge. While the resulting scientific method was ultimately accepted as the framework for conducting deductive research, positivism as a research paradigm was eventually considered too absolute and restrictive in its definition of reality.

Post-positivism complicates the tenets of positivism by acknowledging the role of social constructionism in reality. Reality is still external and objective, but humans observe, interpret, and construct their own interpretations of reality (Miller, 2000). Post-positivism as a research paradigm dictates that human interpretation must be acknowledged when conducting research. Post-positivists essentially concede that humans view and therefore research knowledge through lenses such as prior knowledge, hypotheses and personal values. Researchers identify these biases with the intention of minimizing their impact on the validity of the data (Crotty, 2015). Not only does post-positivism recognize constructionism's role in research construction and analysis, constructionism becomes a topic of research itself. By including human interpretation into the concept of reality, post-positivism expands what is knowable by allowing measurement of constructs, perceptions, feelings, and opinions (Miller, 2000).

A key concept distinguishing positivists from post-positivists is that post-positivists accept the fallibilism of knowledge. Fallibilism is the understanding that empirical knowledge can be revised upon further observation (Reed, 2002). Karl Popper promoted the concept of falsification, or the understanding that knowledge cannot be proven, only disproven, over positivism's verification (1979). What humans understand as measurable, objective, empirical facts are only true in the sense that researchers have not been experimentally able to disprove them. In rejecting the concept of verification, Popper changed the language of research from absolutism to probabilism. In other words, hypotheses are supported, not proven. Bias is limited, not eliminated.

Post-positivism provides a more realistic research paradigm within which to collect social science data (Miller, 2000). By providing a theoretical justification for data collection of human interpretation and/or perception of reality, social scientists and educators are able to measure both external reality and its context within the human experience. Learning is fundamentally a process of internalizing external information and skills, and this process is unique to each individual. Post-positivism allows researchers to capture the phenomenon of learning from both points of view.

Research Design

This study was a concurrent monomethod multistrand, or ‘multimethod’, design (Teddlie & Tashakkori, 2006). Multimethod designs collect either quantitative or qualitative data from multiple sources, then researchers triangulate the results. For this study, summative and formative exam scores of a remote cohort and a F2F cohort were analyzed in order to assess differences in academic outcomes. A Likert-style survey was administered to the remote cohort to assess their perceived anatomical knowledge. The survey’s open response box at the end of the anatomical knowledge section allowed students to leave comments. Textual data from the boxes were analyzed via thematic analysis, and significant findings were added to provide context to otherwise quantitative data. Though a bit of qualitative data was collected, the bulk of the data stems from quantitative sources, thus a QUAN + QUAN research design more accurately describes the study than a mixed methods design (Figure 2). Emergent relationships between the results of the exam score analysis and the survey were assessed to provide a discussion of actual versus perceived anatomical knowledge.

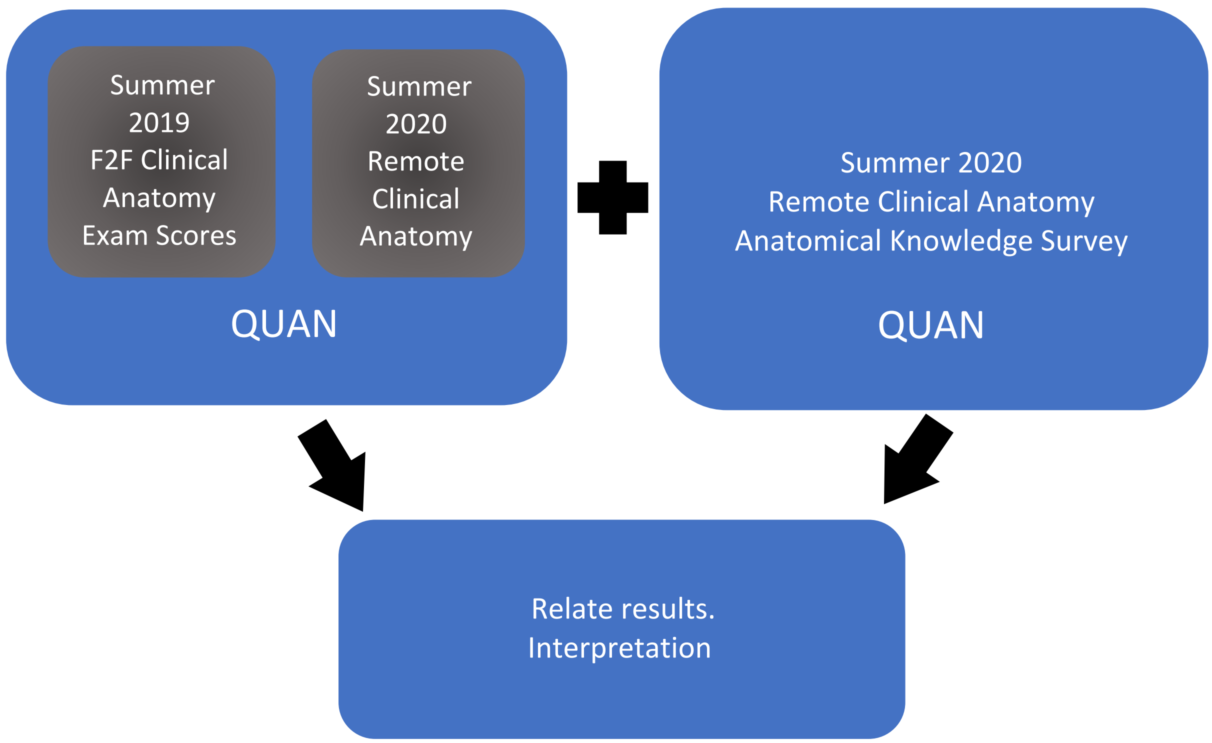
Participants

This study received expedited approval for human participants by the Institutional Review Board at the University of Oklahoma Health Sciences Center in January 2021 (IRB #12937). Informed consent was waived due to the study’s retrospective nature. The 2019 student participant cohort received F2F instruction, while the 2020 student participant cohort received remote instruction during the COVID-19 pandemic. A compilation of student demographic data (Table 1) indicates similarity between the classes. For PA students, 94% of students were between the ages of 21-30 years old in the 2019 cohort, similar to 91% in the 2020 cohort.

Dental student cohorts were similarly close in age, with 88% and 91% of students in the 21-30 years old age category in the 2019 and 2020 cohorts, respectively. The remaining students for all cohorts were aged 31-50. Gender matched closely between PA cohorts: 79% female versus 76% female in 2019 and 2020, respectively. Dental students were not as closely matched between cohorts: 47% of 2019 dental students and 37% of 2020 dental students were female.

Figure 2

Experimental Design Diagram



Note. A concurrent monomethod multistrand design: quantitative data was collected from multiple sources, analyzed separately and ultimately compared with the goal of interpreting anatomical knowledge from a broader perspective than either method alone.

The largest discrepancy in the race and ethnicity data was the difference between the 2019 and 2020 dental students, with 58% versus 70% identifying as Caucasian, respectively. The

2019 dental student population included 20% of individuals identifying as Asian. Though not identical, the student demographic data does indicate consistency between the F2F (2019) and remote (2020) cohorts. Undergraduate GPAs were identical for PA students between years (3.80) and for dental students between years (3.62), indicating academic consistency between the historical control group and the experimental group.

Table 1.

2019 and 2020 PA and Dental Student Demographics

Program	PA (n=50)	Dental (n=54)	PA (n=50)	Dental (n=53)
Age	21-30 31-50	21-30 31-50	21-30 31-50	21-30 31-50
	94% 6%	88% 12%	91% 9%	91% 9%
Gender	79%F 21%M	47%F 53%M	76%F 24%M	37%F 63%M
Race/Ethnicity	81% Caucasian 4.5% Asian 14.5% other	58% Caucasian 20% Asian 22% other	77% Caucasian 5% African-Am. 5% Hispanic 13% other	70% Caucasian 5% Asian 5% Hispanic 20% other
GPA (undergraduate)	3.80	3.62	3.80	3.62

Note. Age, gender, and race/ethnicity provided by the Office of Institutional Research, University of Oklahoma Health Sciences Center, OUHSC. Number admitted and undergraduate GPA for PA students obtained from the Physician Assistant Program in the College of Medicine, OUHSC. Number admitted and undergraduate GPA for dental students obtained from the College of Dentistry, OUHSC.

Data Collection

Assessment Items. Assessment item data from the 2019 and 2020 Clinical Anatomy student populations were retrieved from the learner management system D2L. The assessment items from 2019 and 2020 were compared, and only identical items were used for this analysis. Of the 150 assessment items used for the 3 summative exams, 112 assessment items were identical, excluding 38 from consideration for this study. Student responses for the identical questions were tabulated and used for analysis. All identical data from all students were analyzed from the experimental and control populations. Data from six formative (low-stakes) exams were analyzed, with all 30 assessment items used from each exam.

Additionally, summative assessment items were evaluated according to the Blooming Anatomy Tool, found in Appendix A. (Thompson & O'Loughlin, 2015). This allowed the multiple-choice questions to be categorized into "high" or "low" levels of Bloom's Taxonomy. Bloom's Taxonomy (Bloom, 1956; Anderson & Krathwohl, 2001) is a classification system used to stratify the amount of cognition required to complete an educational objective or answer a question. A high category corresponds to the 'apply' or 'analyze' levels of Bloom's Taxonomy, while a low category corresponds to the 'remember' and 'understand' levels (Thompson & O'Loughlin, 2015). Categorizing the summative assessment items allowed researchers to investigate if the cognitive difficulty of the items was a discriminating factor between the F2F and remote learning groups. Assessment items were also classified by program as either 'dental' or 'PA,' with no other identifying information collected. With this information, researchers determined if program or cognition level according to Bloom is a discriminating factor between F2F and remote learning groups. Formative assessment items were all classified as low Bloom's level.

Clinical anatomy online survey.

Purpose and Administration. The Clinical Anatomy Online Survey (Appendix B), was designed to assess perceptions of anatomical knowledge and to evaluate the laboratory sessions and dissection videos referred to in Chapter 1. Researchers utilized the voluntary response sampling method to recruit students to participate. An invitation was sent to the remote learning cohort via university email accounts on July 22, 2020, and a reminder email was sent out using the same email address on July 25, 2020. A Qualtrics (Qualtrics, Provo, UT) link to the survey was included in the July 22 email. The link remained live for two weeks following the conclusion of the course on July 27, 2020. Ultimately, 60 of 102 (59%) students volunteered to take the survey.

Survey development. Researchers wanted to develop a detailed student evaluation of Clinical Anatomy, and student involvement was considered crucial to developing a relevant survey. Students were invited via email and verbal invitation to participate in a focus group about "how class was going." The focus group took place on July 13, 2020 on a video conferencing call and was recorded. The focus group was conducted on the first day of the third unit; therefore, students had completed two-thirds of the course. The original list of semi-structured focus group interview questions is listed in Figure 3. The questions in bold were the only ones the researcher asked as the students directed the flow of conversation. Thirty-six students attended the conference call, and three students submitted email responses. Non-leading follow-up questions were asked and included "Does anyone have a different perspective?" and "Could you tell me more about that?" Peripheral participants were encouraged to speak or send comments to the researcher (SH) in the chat to be announced anonymously for discussion.

A researcher (SH) transcribed the audio and classified the responses as well as the 3 emails into emergent categories like "anatomy knowledge." As this survey was intended to be a student evaluation of learning clinical anatomy during a pandemic, the researcher (SH) began with broad semi-structured questions, intentionally allowing students to direct the discussion. This was evident in the lack of semi-structured questions specifically addressing anatomical knowledge perceptions. The students were clear and direct about their anatomy knowledge feeling ‘fragmented’ and ‘disconnected from the whole’ and spent several minutes explaining those feelings. Subsequently, the focus of the survey shifted.

Once categorized, responses were pulled from student statements for inclusion into the survey. Where possible, the statements were used verbatim, but frequently neutral statements were created from modified student statements. Two faculty members (NH, MM) met with the researcher (SH) on July 16, 2020 to review the survey draft. The meeting focused primarily on the language and purpose of the survey: clarifying vague statements, neutralizing leading statements, and narrowing the focus. Upon reflection, it was decided that how students perceive their anatomical knowledge was a predominant theme of the focus group and should be one focus of the survey. On July 21, 2020, the researcher (SH) presented to the same group an edited, streamlined survey with a clearer focus of purpose. There was agreement to administer the survey the following day.

Data Analysis

Exam score analysis. Independent sample t-tests were conducted on all assessment item categories to identify any significant differences in academic outcomes between 2019 and 2020. Table 3 (Chapter 4) lists the categories. A 95% confidence interval was calculated for each test, and effect size was calculated for the difference in means for both the summative assessment items and the cumulative formative exams. The assessment item analysis portion of the proposed study utilized a quasi-experimental non-equivalent control group post-test format (Johnson & Christensen, 2016). The assessment items of the 2019 cohort served as the historical control as those students received traditional F2F instruction. The 2020 cohort was the experimental group and received fully remote, synchronous instruction.

Figure 3

Focus Group Interview Questions

1. **How has the pandemic affected you as a student?**
2. Reflect on your experience as a student in a previous laboratory science class. How has being fully online changed your behavior as a student?
3. **What do you do if you have a question or are confused about a topic?**
4. **How are you communicating with each other?**
5. To what extent is this true: I feel as connected to my classmates now as I did in my undergraduate classes. Repeat question with 'professors.'
6. **Can you describe your most successful online study habits?**
7. **How do you use the lab videos?**
8. **Has the absence of cadavers, models, and specimens impacted your learning?**
9. Considering the lack of physical experience with cadavers, models, or specimens, do you feel like you are getting the experience you need to become a clinician?
10. Does the absence of cadavers/dissection influence your specialty preference (if you are planning to specialize?
11. Think back on your experience in anatomy so far. Was there anything you needed to hear or see that would have helped you be successful?

Note. The questions in bold were the ones ultimately asked by the researcher. Students were verbal and directed the flow of conversation. This guideline was originally created to elicit a practical, detailed evaluation of online Clinical Anatomy. Students directed answers toward their feelings regarding learning anatomy and concerns about the adequacy of their knowledge moving forward.

Summative exams. Both cohorts received three summative exams, consisting of 50 multiple-choice questions each. Summative exams were administered at the end of each curriculum unit. Only identical questions that were administered to both cohorts were used in this study. Additionally, the assessment items were evaluated using the Blooming Anatomy Tool (BAT), a rubric designed to categorize items by cognitive difficulty (Thompson & O'Loughlin, 2015). The assessment items were classified independently by two researchers (SH, NH). The researchers met and the initial inter-rater agreement for all assessment items was 57%. Assessment items that were not agreed upon were discussed until agreement was reached. For each of the three summative exams, the overall sum of identical assessment items, the high Blooming assessment items, and the low Blooming assessment items were compared between the F2F and remote cohorts. The cohort categories were further stratified by program to determine any differences between program (Table 3).

Formative exams. The formative exams were spotter exams to identify anatomical structures. The F2F cohort took these exams by rotating through a series of tagged anatomical structures on cadavers, while the remote cohort completed an online digital version of tagged, cadaveric images. Formative exams, or lab practicals, were organized according to a test blueprint to maintain consistency from year-to year. For example, every lab practical has five bone or bone feature identification questions, but which five the students are asked to identify can change from year to year. All formative exam questions were low Bloom's level due to being identification only, but program differences were still assessed.

Clinical anatomy online survey. The Clinical Anatomy Online Survey utilized a quasi-experimental, one-group post-test format (Johnson & Christensen, 2016), which is a snapshot of a group of individuals in a particular point in time. The data collected from the survey was ordinal, so percentages (frequency), were reported in tables. The students' perceptions of anatomical knowledge portion of this study consisted of three nominal data questions followed by 14 statements that students evaluated. There were five Likert-style choices for each statement, ranging from 'not at all true of me' to 'very true of me.' A 5-choice scale was preferred to reduce frustration and improve completion rates (Babakus & Mangold, 1992). Two polar, or yes/no questions were asked, and one open response box with the directions 'Please record any comments or suggestions regarding your understanding of anatomy here' completed the anatomical knowledge section of the survey.

Comments left in the open response box were thematically analyzed and evaluated with the quantitative survey data results. All qualitative data was triangulated by 3 researchers (SH, NH, MM). Researchers met after an initial read-through and coding to assess agreement. A common coding system was negotiated. Next, researchers independently coded all data. Subsequently, researchers reconvened to check the consistency and agreement of coding. Upon agreement, a researcher (SH) assessed the codes for emergent themes and identified representative student data. At a final meeting, all researchers agreed upon the results.

While the assessment items evaluated the cognitive domain of learning, the Online Clinical Anatomy survey asked students to respond to statements categorized by Bloom's Domains of Learning: cognitive, psychomotor/physical, and affective. As previously noted, the modernized Bloom's levels for the cognitive domain classify knowledge acquisition (Anderson & Krathwohl, 2001; Bloom, 1956). The psychomotor domain is defined as the skills obtained through physical movement and coordination, but Harrow's explanation also allows for the use of the term 'physical' instead of psychomotor to indicate knowledge acquired primarily to assist the cognitive domain rather than develop a psychomotor skill set (Harrow, 1972). Arguably, cadaveric dissection represents both physical and psychomotor aspects of the domain, but the majority of survey items reflect the physical rather than the psychomotor intent of cadaveric dissection. The affective domain refers to feelings and perceptions as well as the ability to organize and execute decisions based on valuation (Krathwohl et al., 1964). Table 2 lists the survey items according to domain categorization.

Table 2.

Survey Statements Categorized by Bloom's Domains of Learning

Cognitive	My anatomical knowledge is adequate for where I am in my program.* I am able to picture a muscle or organ as part of a group or system.

	Undergraduate cadaveric anatomy contributed to my three-dimensional understanding of a human body in this course. Activities that integrate lab and lecture knowledge would have contributed to my learning.
Physical (Psychomotor)	I perceive different tissue depths accurately. I can tell tissue textures apart. Studying from physical models would have contributed to my anatomical knowledge. Studying from a three-dimensional online atlas is just as good as studying from physical models. I bought my own model(s) for this course.* Models should be provided by the university for online laboratory courses.* I would like cadaveric review lab time in future classes. Reviewing relevant anatomy on a cadaver in future classes would help me visualize anatomical relationships for the whole body.
Affective	My anatomical knowledge feels fragmented: I cannot see whole body connections. I wanted to dissect a cadaver. I feel behind on surgery skills because I could not dissect. While my grades are acceptable, I’m not sure how well I understand anatomy.

Note: Asterisks indicated researcher-derived statements. All other statements derived from student comments during the focus group.

The following figures group the survey statements analyzed in this study by how they appeared in Qualtrics (Qualtrics, Provo, UT). Students began the survey by choosing which categorical statement suited them best for questions Q3-Q5 (Figure 4). Question 6 (Figure 5) is a series of five statements pertaining to perceived anatomical knowledge. The first statement was generated by researchers, and the remaining four statements were created from the focus group transcripts. Additionally, the final two statements, 'I perceive tissue depths accurately' and 'I can tell tissue textures apart' were independently requested by a faculty member.

Figure 4

Categorical Data Survey Questions

Q3.	Choose one.	I am a dental student. I am a PA student.
Q4.	Choose one.	I completed an undergraduate anatomy course with cadaveric dissection. I completed an undergraduate anatomy course without cadaveric dissection. I did not complete an undergraduate anatomy course.
Q5.	Choose one.	Ability to participate in cadaveric dissection enhanced my interest in applying to OUHSC. Ability to participate in cadaveric dissection did not enhance my interest in applying to OUHSC.

Note. Researchers determined that knowing a) program of study b) previous anatomy/dissection experience and c) importance of cadaveric dissection in application decision would help in the analysis phase of the survey. (See Appendix B).

Figure 5

Survey Statements from Question 6

My anatomical knowledge is adequate for where I am in my program.
My anatomical knowledge feels fragmented: I cannot see whole body connections.
I am able to picture a muscle or organ as part of a group or system.
I perceive different tissue depths accurately.
I can tell tissue textures apart.

Note. Perceived anatomical knowledge statements for evaluation. These statements correspond to Q6 of the survey (See Appendix B).

Figure 6

Survey Statements from Question 7

I wanted to dissect a cadaver.
I feel behind on surgery skills because I could not dissect.
Studying from physical models would have contributed to my anatomical knowledge.
Studying from a three-dimensional online atlas is just as good as studying from physical models.

Note. Additional statements for evaluation derived from the focus group transcript. These statements correspond to Q7 of the survey (See Appendix B).

Figure 6 is a list of four additional statements derived from student comments during the focus group. The last statement 'Studying from a three-dimensional online atlas is just as good as studying from physical models' was constructed by the researcher after two students in the focus group disagreed on the need for physical models. Figure 7 is a list of yes/no questions generated by the researcher after a few students in the focus group stated they had bought a skull model to learn the osteology of the head. No students suggested that the university should provide models during remote learning; the second question was included by the researcher as a follow-up to the first question. Figure 8 lists the last grouping of statements, and all were directly derived from students during the focus group.

Figure 7

Survey Questions Regarding Models

I bought my own model(s) for this course. Yes or No
Models should be provided by the university for online laboratory courses. Yes or No

Note. Statements regarding the use of models during remote learning. These questions correspond to questions 8 and 9 (Q8, Q9) in the survey.

Figure 8

Survey Statements from Question 10

Undergraduate cadaveric anatomy contributed to my three-dimensional understanding of a human body in this course.
Activities that integrate lab and lecture knowledge would have contributed to my learning.
While my grades are acceptable, I'm not sure how well I understand anatomy.
I would like cadaveric review lab time in future classes.
Reviewing relevant anatomy on a cadaver in future classes would help me visualize anatomical relationships for the whole body.

Note. The final grouping of statements was derived directly from student statements transcribed from a focus group. These statements are question 10 (Q10) in the Qualtrics survey.

Validity. Validation is the process of establishing an evidence-based justification for the uses of assessments (Tavakol & Dennick, 2017). Validity discussions should attempt to answer the question: Are the conclusions and interpretations drawn from data appropriate? Kane offers a four-part framework based on creating an argument for the proposed use of interpretations that allows for the validation of both quantitative and qualitative data. The framework levels are scoring, generalization, extrapolation, and implications (Kane, 2013). Scoring refers to individual measurements or observations with the intent of supporting validity by indicating the fairness, accuracy, and reproducibility of the item. Generalization refers to the representativeness of the selected measurements. Few assessments cover every possible item in a learning domain, so an assessment score should be a representative sample of all possible items. Reproducibility indicators and sampling strategies provide evidence for generalization. The next level, extrapolation, refers to the degree to which the assessment reflects a real performance. Validity evidence at the extrapolation level could be demonstrated by correlating the assessment to a criterion-referenced measure or a needs analysis to define the scope of an assessment. Implications, the final stage of Kane's framework, refers to any planned action based on the interpretation of the assessment. Long-term evaluation of the consequences of a decision based on assessment interpretation could support the implications stage of a validity assessment (Cook et al., 2015).

Kane's interpretation-use argument (IUA) framework is flexible in its application. The IUA framework can be used for an assessment within a course/program or a research study to justify a use of the interpretation of data (Kane, 2013). For this study, researchers sought to validate the comparison of identical assessment items from the 2019 and 2020 cohorts in order to assess remote learning. To make that comparison, the assessment items also had to be validated as authentic measurements of anatomical knowledge. Additionally, researchers sought to validate the use of the student perspectives of anatomical knowledge survey. The remainder of this section is a discussion of the evidence in support of these stated uses.

Assessment Items - Summative. Each assessment item is one multiple choice question, or one observation in Kane's IUA framework. For this study, each assessment item was used to assess both cohorts. In both years, faculty systematically assessed the statistical performance of each assessment item by two measures: item difficulty and point biserial correlation. Item difficulty is the percentage of correct responses for an individual item. Ranging from 0 (no one answered the question correctly) to 1 (everyone answered the question correctly, a range between 0.3-0.8 indicates an acceptable level of difficulty for an item (Tavakol & Dennick, 2011). Item discrimination was assessed by calculating the point biserial correlation. The point biserial correlation ranges from -1 to 1, with the individual test item response correlated to the overall exam score. A score of 0.25+ indicates an acceptable correlation. A high correlation indicates students that scored higher on the exam got the test item correct whereas the lower scoring students did not get the test item correct (Tavakol & Dennick, 2017). Upon review, the faculty decided whether or not to cull the question. A question that was considered by faculty to be essential knowledge may not have a high point biserial correlation or contribute to the reliability of the exam. The importance of the knowledge, however, superceded the item analysis data in this case.

Faculty used a test blueprint in order to provide a consistent sampling of content. The number of questions on summative exams (50) was divided by the number of lectures in the unit, typically resulting in four or five questions per lecture. Newly written questions were compared to the learning objectives to ensure consistency to the stated Bloom's Taxonomy level. Approximately 31% of the questions were written in a clinical vignette style, consistent with licensing examinations. The remainder were written according to current item writing best practices in medical education. The test blueprint process promotes the concept of the assessment items used in the exams as accurate representatives of all possible assessment items (Downing, 2003).

A test blueprint also maintained assessment consistency between cohorts; however, reliability is the most common method of assessing performance consistency. Reliability of the assessment items was measured using the Kuder Richardson 20 formula (KR-20). The KR-20 is a measure of the probability of getting the same results if the exam was administered to a similar group of students. Generally, the higher the variability in scores, the higher the reliability. The range of reliability coefficients for the summative assessment items ranges from 0.88-0.96, with 0.70+ considered an acceptable coefficient. The reliability coefficients for the assessment items, combined with the test blueprint, provided evidence of generalization (McGahee & Ball, 2009; Tavakol & Dennick, 2017).

As Kane noted, generalization and extrapolation are inversely related (Kane, 2013). Extrapolation is the correlation of the assessment items to real world situations. The standardization and representativeness promoted as features of generalization limit the degree to which assessment item data correlates to a practical experience (Cook et al., 2015). Neither cohort have taken a similar anatomy or licensure exam at this point to compare data points. The best evidence of extrapolation for the assessment items in this study was the attention paid to item writing. Assessment items written as clinical vignettes were modeled after assessment items students will encounter when taking licensing and certification exams. Since this study did not attempt to extrapolate information to apply beyond a curriculum assessment of clinical anatomy, weak extrapolation evidence was not considered a reason to invalidate the study.

The implications, or planned actions upon data analysis, were limited to potential curricular changes to the Clinical Anatomy curriculum based on student performance. The validating evidence supported the assessment items as authentic indicators of anatomical knowledge and as the basis of comparison of cohort performance. The implications for the use of the formative exams in the research study are the same, but the evidence of their validity differs.

Assessment Items - Formative. The six formative exams for Clinical Anatomy consisted of 30 anatomical identification questions each. The 2019 F2F cohort viewed tagged cadavers, and the 2020 remote learning cohort viewed edited cadaveric images. Editing the cadaveric images consisted of adding an arrow to point to a specific location, adding a text box with directions (i.e. ‘Name the structure’), and occasionally providing an additional image for orientation purposes. Scoring evidence for a fill-in-the-blank spotter-style exam was determined by evaluating of the accuracy and appropriateness of each question. Cadavers were routinely reviewed for multiple correct answers/interpretations of the tag, and dissection work to prepare the tagged cadavers were scrutinized for neatness and accuracy. When viewing a physical cadaver, orientation of the head and limbs helps a student orient the structure, and the ability to orient a detailed digital image can be difficult. Video images showing orientation and/or zooming out where appropriate served to emulate the orientation cues provided by a cadaver. Generally, though the format of the exams differed, every attempt was made for the same observation effect for the video questions as the cadaver tags.

Similar to the summative assessment items, faculty utilized a test blueprint to create the formative exam content. Explained in the Data Collection section, the blueprint was also followed when constructing video formatted exams and provided consistency between the cohorts. The test blueprint as a template allowed for reliable sampling from all possible tagged structures, whether cadaveric or digital (Downing, 2003). No quantitative data was collected for the extrapolation of data, but ‘high value’ knowledge, or anatomical information likely to be seen again in a future exam or clinical simulation, were frequently emphasized. The curricular purpose of the formative exams was to provide students with evidence of their learning in real time. Tagged cadavers and video images were used to create exceptionally authentic assessments of low Bloom’s level anatomical knowledge. For the study, the formative exams represented a main source of pedagogical difference; the 2020 cohort received no in-person cadaveric laboratory instruction. Students watched videos and attended ‘dry lab’ videoconferencing sessions modeled after the F2F cadaveric laboratory experience. The evidence provided demonstrates how formative exam development processes support a consistent learning experience between years and delivery formats. The standardization of the formative exam experience provided sufficient evidence for the validity of comparing formative exams as one measure of assessing anatomical knowledge.

Survey. The purpose of the Clinical Anatomy online survey component used in this study was to determine students' perceptions of their anatomical knowledge. The survey was designed from a semi-structured focus group interview of students by the lead teaching assistant (SH). Questions and prompts (Figure 2) were written to initiate a rich conversation between students. The transcription of this interview provided the material for survey construction. As noted in the Data Collection section, a researcher (SH) met with faculty (NH, MM) twice to review the transcription statements and identify items for inclusion. This process of construction, triangulation, and agreement of the categorization and inclusion of items supported the use of the survey as a mechanism to provide students with a voice regarding the course (Cook et al., 2015).

Generalization evidence was limited in this situation as both the pandemic and remote Clinical Anatomy are two exceptional events. Additionally, this survey was developed from student input from one course on one campus. Researchers used the voluntary sampling method, thus students self-selected into participating in this survey. The data may be skewed toward those compelled to communicate. A factor in favor of the representativeness of the survey data was that 60 of 102 (59%) students participated in the survey.

In allowing students' concerns and needs drive the interview, students were permitted to define the scope and purpose of the subsequent survey. Though lacking in standardization, the survey was relevant and authentic to students. Authenticity to students' lived experiences provided support for the real-world utility of this survey. The implications for the survey were within the boundaries its construction. Student perspectives derived from the survey informed faculty of how students felt about their anatomical knowledge and provided context relatable to assessment items. Knowledge of what OUHSC PA and dental students experienced at a very unique time in history provided insight that could assist anatomy educators when providing future curricular innovations.

Threat Assessment. Another framework from which to evaluate the validity of a study is to assess the external and internal threats to validity based on the study's construction. Threat assessment is useful as a means of evaluating the limitations of the study design in order to ensure the conclusions drawn from the data are appropriate (Downing, 2003). Regarding the assessment item analysis, there are multiple potential threats to external validity when conducting a quasi-experimental study. The main threat concerns the lack of randomization of the students. Common to education, researchers frequently study naturally occurring cohorts rather than randomly sorting students into control and experimental groups, thus the 'quasi-experimental' label (Johnson & Christensen, 2016). The concern is that if the populations are unique, the results will not be generalizable to other PA and dental programs at similar institutions. The justification of the 2019 F2F cohort functioning as the historical control was the similarities of the student cohort populations (Table 1). Though demographically similar, the 2019 F2F cohort must be considered a non-equivalent control group due to the lack of randomization.

Other typical external validity threats did not significantly affect assessment item analysis. The 2020 cohort acceptance and decision deadlines to the dental or PA programs occurred prior to the onset of COVID-19, eliminating the pandemic as an historic influence on decisions to attend. Sampling bias was not a factor due to all identical assessment items being utilized. Other threats to external validity (treatment diffusion, maturation, selection bias) were irrelevant due to the retrospective nature of the data collection.

Internal validity is the degree to which a cause-and-effect relationship can be determined in a study (Slack & Draugalis, 2001). Said another way, internal validity increases as more variables are eliminated. The lack of randomization was also a potential threat to internal validity. Since the students weren't sorted into groups from the same pool of participants, the two cohorts may be inherently different and introduce an unknown variable. COVID-19 itself is an historical threat to internal validity. There is no way presently to quantify the emotional impact or the cognitive load of beginning professional school in the middle of a pandemic. The proposed study assesses remote learning of clinical anatomy during a pandemic, and with no way to measure the pandemic's effects on individuals, the pandemic remains a confounding covariate.

As for the survey, quasi-experimental, one-group post-test surveys are essentially one-shot case studies (Campbell & Stanley, 1967), and the threats to internal validity are significant. Most acutely, there was no control group to compare results (Johnson & Christensen, 2016). Due to the rapid onset of COVID-19 and the fact that Clinical Anatomy meets annually for 7 weeks, there was no possible way to administer this survey to a non-pandemic cohort at the same time-point in their schooling. The result was the survey data collected was essentially narrative in rigor even though the data is numerical in nature.

The construction process of the survey potentially allowed for two external threats to validity. Students were invited to participate in a focus group to provide survey construction data for the researcher. While not a true testing effect, participating in a large focus group may have changed the perceptions students held prior to the administration of the survey. Consistent with the quasi-testing effect, a maturation effect was possible in that students may reflect on a completed course differently than one in which they currently participate (Campbell & Stanley, 1967). With the limitations noted, gathering data in the students' voices allowed faculty a window into the minds of students during a historically unique time.

Multimethod triangulation. In this study, triangulation referred to relating assessment items to survey data where possible. After assessing the difference in means of assessment items, the results were discussed in the context that the survey data provided. Significant findings will be displayed graphically, with contextual survey results highlighted in text boxes nearby.

Conclusion

The purpose of this research was to determine the effects of remote Clinical Anatomy during a pandemic on actual and perceived anatomical knowledge. In the next chapter, a statistical analysis of assessment items will provide a quantitative approximation of actual student knowledge. Additionally, the student survey data will be presented and discussed. Including students in the construction of the student perspectives survey provided an authentic tool for students to amplify their voices regarding their concerns about their anatomical knowledge. The final component of the next chapter will be the presentation of relationships between actual and perceived knowledge. These findings potentially provide insight for faculty to construct meaningful changes to the clinical anatomy curriculum.

Chapter 4: Results and Analysis

This chapter will present the actual and perceived anatomical knowledge data. Actual knowledge, determined for this study to be summative and formative assessment items, were compared between a remote cohort and a face-to-face (F2F) cohort. Perceived anatomical knowledge was a student perspectives survey for this study. A data analysis, including a multimethod triangulation to determine if any relationships exist between actual and perceived knowledge, will conclude the chapter.

In light of the lack of knowledge of best practices for remote clinical anatomy, explaining and evaluating curricular changes is a necessary first step toward identifying what anatomy educators want to continue in their praxis for remote learning during a pandemic and potentially beyond. Two common practices in medical education are to evaluate the academic outcomes and student perceptions of a curricular change. Based on Kirkpatrick's four levels of training evaluation (Kirkpatrick & Kirkpatrick, 2016), the first two levels are 'reaction' and 'learning'. Essentially, Kirkpatrick posits that to know the effects of training, researchers must first study how trainees perceive the training and what the trainees learned. Once that data is established, researchers can then investigate if trainee behavior changed as a result of the training and if the behavior change causes an institutional change. Though the original model has been modified to include that researchers do not necessarily have to investigate the levels in order, the convention in medical education remains that evidence of curriculum changes in the absence of academic outcomes assessments is limited.

The response to COVID-19 offered anatomy educators a unique opportunity to investigate fully remote clinical anatomy. The majority of anatomy educators taught with cadaveric dissection in the laboratory prior to 2020 (McBride & Drake, 2018). Switching to remote learning represented a dramatic shift in how laboratory content was offered. Laboratory was a place of formative, or low-stakes learning, and changing how it was offered in a clinical anatomy course may impact students' academic outcomes. One purpose of this study was to determine if the academic outcomes of a F2F course differed from a remote course. Summative and formative assessments were statistically analyzed for significant differences in means. A second purpose of this study was to assess student perspectives of their anatomical knowledge. The final purpose was to see what/if any relationships existed between students' actual and perceived anatomical knowledge.

This chapter begins with a discussion of academic outcomes results, both summative and formative. Recall from chapter 3 that the statistical analysis consisted of T-tests between the F2F 2019 cohort data and the remote 2020 cohort data. The summative exams were additionally analyzed by program (dental or PA) and Bloom's level (high or low). The formative exams (laboratory practical exams) were analyzed by program as well. The Clinical Anatomy Online Learning Survey results are discussed after the academic outcomes section. The chapter concludes with data analysis of the components as well as an evaluation of relationships between academic outcomes and student perceptions of their anatomical knowledge.

Results

Academic Outcomes. For both Clinical Anatomy cohorts, three summative exams were administered at two-week intervals, featuring content of the extremities and back, head and neck, and thoracic/abdominal cavities, respectively. A total of 150 multiple choice questions were administered to students in the three exams, and 99 questions are included in this study. The 99 questions, or assessment items, were offered to both the 2019 and 2020 cohorts. In 2020, the course was expanded by one week to front-load embryology and histology lecture material and to introduce remote laboratory procedures. A 'mini-summative' quiz of 30 questions was administered prior to the three previously mentioned. Ten of the questions that appeared on the 2019 Summative Exam 1 were on the 2020 Mini-Summative Quiz and included in this study. The remaining 89 assessment items analyzed in the study were administered to students in the three main summative exams.

For both the 2019 and 2020 cohorts, six weekly practical laboratory exams were administered to provide students feedback regarding the progress of their learning. These formative, low-stakes assessments consisted of 30 identification items. In 2019, the items were tagged on multiple cadavers, but in 2020 the items were tagged on digital images and administered remotely.

Summative. Independent t-tests were conducted on the assessment items and were classified by the following categories: year, program, and Bloom's Taxonomy level (Anderson & Krathwohl, 2001; Bloom, 1956). For the year and program, each student's score (number of correct answers obtained per student) was summed for each category of questions and divided by the number of students to determine the mean. Each question's score (number of correct answers obtained) was calculated for the Bloom's high level questions and for the Bloom's low level questions. The mean was then calculated from the sums for both categories divided by the number of questions. The summative assessment items statistical analysis was conducted using SAS© Enterprise Guide 7.1 (SAS Institute, Incorporated. Cary, North Carolina). Prior to comparing assessment item means in a t-test, the homogeneity of variances (homoscedasticity) was assessed. Variance measures the spread between numbers in a data set, and t-test calculations differ depending on whether the variances are equal or unequal (Johnson &

Christensen, 2016). For the summative exam assessment items, all of the comparisons had equal variances as determined by the Folded F test.

Two additional comparisons were made between the high and low Bloom's level assessment items for each program to assess the validity of the Bloom's levels. Both comparisons had unequal variances, so the Satterthwaite method of assessing variance was applied. The Satterthwaite method utilizes a weighted average of variances as opposed to a regular average. A weighted average, instead of the pooled (straight) averages found in equal variances, mathematically corrects non-homogeneous variances so that the test statistic comparison has meaning (Johnson & Christensen, 2016). A weighted average also requires mathematically determining the degrees of freedom rather than a simple sum. All f-tests and variance data for summative academic outcomes is found in Appendix C. Table 3 contains the summary of t-test data for the summative assessment items.

Table 3

Summative Assessment Items T-test Results

Category	Year	N	Mean	95% CL Mean		Std Dev	DF	t Value	Pr > [t]
Year Overall	2019	104	78.4808	76.889	80.0725	8.1847	204	-2.07	.040*
	2020	102	81.0784	79.1512	83.0056	9.8118			
Dental	2019	56	77.75	75.4838	80.0162	8.4622	107	-0.19	0.85
	2020	53	78.0943	75.1953	80.9934	10.5179			
PA	2019	48	79.3333	77.0538	81.6129	7.8506	95	-3.11	.0025*
	2020	49	84.3061	82.0397	86.5725	7.8904			
Bloom's High	2019	32	76.2188	69.6598	82.7777	18.192	62	-0.84	0.4
	2020	32	79.75	74.2287	85.2713	15.3139			
Bloom's Low	2019	67	82.806	79.3452	86.2668	14.1884	132	-1.14	0.26
	2020	67	85.3433	82.5346	88.152	11.5149			

Note: *Significance threshold at the $p < 0.05$ level. Orange shading to highlight significance.

The mean for the 2020 remote assessment items was 81.08, which was significantly higher than the 2019 F2F mean of 78.48, p = .040, d = 0.29. For the program assessment items, dental students' means from 2019 were compared to dental students' means from 2020, and the same calculations were made for PA students. Dental student means were 77.75 and 78.09 for

2019 and 2020, respectively, and the difference was not significant. PA student means on assessment items, however, did reach significance. For 2019 and 2020, the means for PA assessment items were 79.33 and 84.31, respectively, $p = .0025$. The results indicated that the 2020 cohort of remote learners performed better than the 2019 cohort of F2F learners, and the difference was almost entirely attributable to the PA students' performance.

For the Bloom's level analyses, 32 of the 99 assessment items were considered high Bloom's level (apply or analyze), and 67 assessment items were considered low Bloom's level (remember or understand). The results of all high Bloom's level questions from 2019 were compared with the results of 2020. The same comparison was made for the low Bloom's level. To obtain the means, the sum of points earned per question for each category were averaged for 2019 and 2020. Though the means for 2020 were higher for both Bloom's levels, neither the high Bloom's level nor the low Bloom's level difference in means reached significance (Table 3). Ultimately, Bloom's level did not appear correlated to remote and F2F learning differences.

The difference in means *between* high and low Bloom's questions was assessed for each program. The dental Bloom's high level mean was 74.54, while the mean for the Bloom's low level was 80.69 for 2020, $p = .001$. Similarly, the PA Bloom's high level mean was 78.74, while the mean for the low level was 84.55, $p = .001$ (Appendix D). The means for the Bloom's high level were significantly lower than the means of the Bloom's low level for both dental and PA programs. Students of both programs scored significantly lower on the Bloom's high level questions than on the Bloom's low level questions.

Formative (low-stakes). Independent t-tests were conducted on the weekly formative exams. Each of the six exams were analyzed by year and program. Examining the formative exams by week was appropriate due to the volume of changes made to the laboratory versus the lecture components of the course. Analysis of each week of formative exams was also consistent with the concept of matching the statistical analysis to the intervention, mentioned previously in chapter 2 (Morton & Colbert-Getz, 2017). Each student's score (number of correct answers) was calculated for each week to determine the overall means for analysis. Student scores were separated by program and week to determine the program analyses. All formative analyses were calculated in Microsoft© Excel Version 16.46. Similar to the summative assessment items, F-tests were conducted to determine the homogeneity of variance for each test. F-test results are in Appendix E. Table 4 contains the summary of t-test data for the summative assessment items.

Table 4

Formative Exam T-test Results

	Mean			T-test Comparison		
Sample	2019	2020	df	t Stat	tcritical	p-value
Overall				t < tcritical	*significance	
Week 1	26.3341346	22.9852941	156	-5.5145077	1.97528751	< .001*
Week 2	21.5336538	25.1470588	204	-6.6469772	1.97166089	< .001*
Week 3	26.7211538	27.5686275	204	2.02747325	1.97166089	.044*
Week 4	24.0096154	25.4460784	204	-3.1701023	1.97166089	.0018*
Week 5	26.7794118	25.2058824	168	-3.9259202	1.97418519	< .001*
Week 6	22.8932039	25.3970588	203	-5.3096357	1.97171885	< .001*
Dental						
Week 1	25.53125	21.7924528	78	-4.1797915	1.99084707	< .001*
Week 2	21.2589286	24.2924528	107	3.82638519	1.98238337	< .001*
Week 3	26.6517857	26.6792453	97	0.042792	1.98472319	0.97
Week 4	23.3214286	24.8584906	107	2.46059577	1.98238337	.016*
Week 5	26.4537037	24.0849057	79	-4.039817	1.99045021	< .001*
Week 6	22.3482143	24.2641509	107	-2.7431825	1.98238337	.0071*
PA						
Week 1	27.2708333	24.2755102	74	-3.9520083	1.9925435	< .001*
Week 2	21.8541667	26.0714286	95	-5.8836233	1.985251	< .001*
Week 3	26.8020833	28.5306122	79	-3.4741836	1.99045021	< .001*
Week 4	24.8125	26.0816327	95	-2.0033252	1.985251	.048*
Week 5	26.4183673	27.1458333	95	-1.4905912	1.985251	0.14
Week 6	23.5425532	26.622449	94	-5.4727725	1.98552344	< .001*

Note: *Significance threshold at the $p < 0.05$ level. Orange shading = significant 2020 results. Green shading = significant 2019 results.

Overall, the 2020 remote cohort formative exam scores were 0.58 points higher than the 2019 F2F cohort scores, $p = .008$, $d = 0.15$. Sixteen of the 18 formative exam differences in means between 2019 and 2020 were statistically significant. For week 1, the 2019 F2F cohort means were significantly higher for all categories. In week 2 the 2020 remote cohort averages were greater, again for all categories. Week 3 data diverged; overall and PA means were higher for the 2020 remote cohort, with no significant difference in means for dental students. Week 4 data was consistent for all categories, with the 2020 cohort means significantly higher than the 2019 F2F cohort. Week 5 deviated from the previous three weeks; the 2019 F2F cohort means were significantly higher for dental students and students overall. PA means' differences for week 5 were not statistically significant. Week 6 results were consistent with weeks 2 and 4 in that the 2020 remote cohort means were significantly higher than the 2019 F2F means. For the 2020 remote cohort, a total of four of the six exams were significant for the students overall and PA students specifically, and three of the six exams were significant for the dental students. For the 2019 F2F cohort, a total of two of the six exams were significant for the students overall and dental students specifically, and one exam was significant for PA students. Though there were a few inconsistencies and the effect size was small, the results suggest that the 2020 remote cohort performed slightly better than the 2019 F2F cohort after week 1.

Clinical Anatomy Online Learning Survey. Student were invited to participate in a survey to determine their perceptions regarding their anatomical knowledge. All students (n=102) were invited, and 60 (59%) participated. Of those 60 students, 24 were from the dental program and 36 were from the PA program. Of the 24 dental students, seven participated in cadaveric dissection at the undergraduate level, and 11 completed undergraduate anatomy without cadaveric dissection. Seven dental students did not take an undergraduate anatomy course. Undergraduate anatomy was required for the 36 PA students, with 19 of the 36 participating in an anatomy course with cadaveric dissection. When asked if participating in cadaveric dissection enhanced their interest in applying to the program, dental students were fairly split, with 10 answering 'yes' and 14 answering 'no.' PA students were more likely to answer 'yes,' with 29 of 35 answering affirmatively (1 PA student declined to answer).

Most of the remainder of the questions were statements with a Likert-style, 5-point rating scale. Answer choices ranged from 'very true for me,' 'fairly true for me,' somewhat true for me,' 'not very true for me,' and 'not at all true for me.' Recall from chapter 3 that the statements were largely derived from a focus group of PA and dental students, with faculty making adjustments for clarity and neutrality. Overall student data, along with separated dental and PA student data, are found in Table 5 below. Dental and PA results were further broken out by their undergraduate anatomy status and were included in the discussion if there was a relevant finding. Undergraduate anatomy status by program results are found in Appendix F.

Statement 1 was designed to solicit general student opinion about their anatomical knowledge in the context of their beginner status. The majority of participants, 72%, indicated that statement 1 was 'very' or 'fairly' true for themselves. Another 20% indicated the statement was 'somewhat' true, with 8% selecting 'not very true for me.' The PA and dental student specific data denoted a similar trend. Statement 2 addressed fragmented anatomical knowledge perception, and the question was written as a negative statement. Fifty percent of survey participants indicated that the statement was 'not very' or 'not at all true for me,' indicating they did not feel their knowledge was fragmented. 'Somewhat' true was selected 34% of the time, and 16% indicated that statement 2 felt 'very' or 'fairly' true for them. The PA and dental student specific data denoted a similar trend. Of the 18 dental students responding 'somewhat' or 'not very' true for me, 14 of those students had previous undergraduate anatomy experience (Appendix F).

Statement 3 addressed students' abilities to perceive an anatomical component (muscle or organ) as part of a larger system. A full 93% of students indicated this statement was 'very,' 'fairly,' or 'somewhat true for me.' Of the 11% of the 36 PA students indicating 'not very' or 'not at all true,' the majority (three out of four) of those students did not perform cadaveric dissection in their undergraduate anatomy course.

Statements 4 and 5 addressed tissue depths and textures. For statement 4, 85% of students indicated the statement was 'very', 'fairly' or 'somewhat true for me,' and the percentages were distributed evenly among the three choices. The remaining 15% selected 'not very true for me,' and there were no distinctions between those students as to their undergraduate anatomy status. For statement 5, the positive versus negative outcomes were similar to statement 4, with 88% of students selecting 'very,' 'fairly,' or 'somewhat true for me.' Twelve percent indicated that statement 5 was 'not very' true. The percentages are less evenly distributed than the statement 4 results, however, with only 15% selecting 'very' true, 45% selecting 'fairly' true, and 28% selecting 'somewhat true for me.'

Table 5

Clinical Anatomy Online Learning Survey Question 6					
Statement 1 My anatomical knowledge is adequate for where I am in my program.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total (n=60)	20 (34%)	23 (38%)	12 (20%)	5 (8%)	0 (0%)
Dental (n=24)	8 (33%)	8 (33%)	5 (21%)	3 (13%)	0 (0%)
PA (n=36)	12 (33%)	15 (42%)	7 (19%)	2 (6%)	0 (0%)
Statement 2 My anatomical knowledge feels fragmented: I cannot see whole body connections.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	2 (3%)	8 (13%)	20 (34%)	24 (40%)	6 (10%)
Dental	2 (8%)	2 (8%)	9 (38%)	9 (38%)	2 (8%)
PA	0 (0%)	6 (17%)	11 (31%)	15 (42%)	4 (11%)
Statement 3 I am able to picture a muscle or organ as part of a group or system.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	23 (38%)	25 (42%)	8 (13%)	3 (5%)	1 (2%)
Dental	11 (46%)	10 (42%)	3 (13%)	0 (0%)	0 (0%)
PA	12 (33%)	15 (42%)	5 (14%)	3 (8%)	1 (3%)
Statement 4 I perceive different tissue depths accurately.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	16 (27%)	17 (28%)	18 (30%)	9 (15%)	0 (0%)
Dental	9 (38%)	5 (21%)	8 (33%)	2 (8%)	0 (0%)
PA	7 (19%)	12 (33%)	10 (28%)	7 (19%)	0 (0%)
Statement 5 I can tell tissue textures apart.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	9 (15%)	27 (45%)	17 (28%)	7 (12%)	0 (0%)
Dental	5 (21%)	9 (38%)	7 (29%)	3 (13%)	0 (0%)
PA	4 (11%)	18 (50%)	10 (28%)	4 (11%)	0 (0%)

The first two statements of question 7 (Table 6) addressed the lack of cadaveric dissection. Ninety-five percent of students indicated a desire to dissect a cadaver, with 79% selecting ‘very’ or ‘fairly true for me.’ ‘Very true for me’ was indicated at a higher percentage of PA students than dental students, 60% versus 46%, respectively. Statement 2 results had a larger spread than most other responses of this survey, and the PA and dental responses were divergent. For the total responses, 45% indicated that feeling behind on surgery skills was ‘very’ or ‘fairly true for me,’ and 22% indicated the statement was ‘somewhat true for me.’ Thirty-three percent of students felt the statement was ‘not very’ or ‘not at all true’ for them. The extreme answer choices diverged for PA and dental students, with 43% of PA students and just 13% of dental students selecting ‘very true for me.’ The ‘not at all true for me’ values were inverted, with only 5% of PA students versus 21% of dental students selecting that answer choice.

Statements 3 and 4 of question 7 referred to the use of models for studying. Fully 98% of participants indicated that having physical models would have contributed to their anatomical knowledge, with the largest percentage (67%) indicating statement 3 was ‘very true for me.’ Statement 4 extended the line of questioning to include the adequacy of three-dimensional, online models. ‘Not very’ or ‘not at all true for me’ choices were selected by 58% students, and 28% indicated the statement was ‘somewhat true for me.’ Just 14% of students chose ‘very’ or ‘fairly true for me.’

Table 6

Clinical Anatomy Online Learning Survey Question 7

Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Statement 1 I wanted to dissect a cadaver.					
Total (n=59)	32 (54%)	15 (26%)	9 (15%)	1 (2%)	2 (3%)
Dental (n=24)	11 (46%)	7 (29%)	4 (17%)	0 (0%)	2 (8%)
PA (n=35)	21 (60%)	8 (23%)	5 (14%)	1 (3%)	0 (0%)
Statement 2 I feel behind on surgery skills because I could not dissect.					
Total (n=59)	18 (31%)	8 (14%)	13 (22%)	12 (20%)	8 (13%)
Dental (n=24)	3 (13%)	5 (21%)	8 (33%)	3 (13%)	5 (21%)
PA (n=35)	15 (43%)	3 (5%)	9 (26%)	5 (14%)	3 (5%)
Statement 3 Studying from physical models would have contributed to my anatomical knowledge.					
Total (n=58)	39 (67%)	11 (19%)	7 (12%)	1 (2%)	0 (0%)
Dental (n=24)	16 (67%)	3 (13%)	4 (17%)	1 (4%)	0 (0%)
PA (n=34)	23 (68%)	8 (24%)	3 (9%)	0 (0%)	0 (0%)
Statement 4 Studying from a three-dimensional online atlas is just as good as studying from physical models.					
Total (n=58)	4 (7%)	4 (7%)	16 (28%)	24 (41%)	10 (17%)
Dental (n=24)	3 (13%)	2 (8%)	5 (21%)	9 (37%)	5 (21%)
PA (n=34)	1 (3%)	2 (6%)	11 (32%)	15 (44%)	5 (15%)

Table 7

Clinical Anatomy Online Learning Survey Question 8 & 9			
Question 8 I bought my own model(s) for this course.			
Program	Yes	No	
Total (n=60)	15 (25%)	45 (75%)	
Dental (n=24)	6 (25%)	18 (75%)	
PA (n=36)	9 (25%)	27 (75%)	
Question 9 Models should be provided by the university for online laboratory courses.			
Program	Yes	No	
Total	47 (78%)	13 (22%)	
Dental	19 (79%)	5 (21%)	
PA	28 (78%)	8 (22%)	

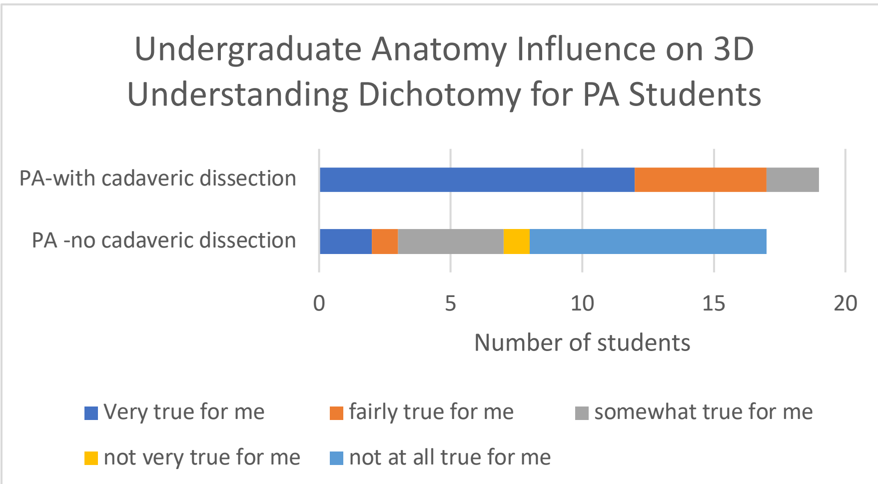
Questions 8 and 9 (Table 7) completed the series of statements regarding models. When asked if students purchased models for the course, 25% answered affirmatively, and 75% answered negatively. When classifying students by their previous anatomy experience, dental students who did not take undergraduate anatomy were approximately half as likely to buy a model than students who did take a previous anatomy course (Appendix F). PA students without cadaveric dissection as an undergraduate were less likely to buy a model than students that did dissect in their undergraduate anatomy course. When asked if the university should provide models for study, 78% of students responded affirmatively, and 22% answered negatively. Percentages for PA and dental students were consistent with the total percentages, and previous undergraduate anatomy experience did not factor into the results.

Question 10 (Table 8) consisted of 5 statements and concluded the quantitative anatomical knowledge perception portion of the survey. When asked to evaluate how much their undergraduate course contributed to their three-dimensional understanding in Clinical Anatomy, 36% of students selected ‘not very’ or ‘not at all true for me.’ Removing the dental students that had no undergraduate anatomy experience from the calculation dropped the total negative responses to 28%. Total affirmative responses ranged from 32% choosing ‘very true’ to 17% and 15% for ‘fairly’ and ‘somewhat true for me,’ respectively.

For the PA students, whether or not their undergraduate anatomy experience included cadaveric dissection affected their response to how much their undergraduate anatomy course influenced their understanding of three-dimensional anatomy in clinical anatomy (Figure 9). Of the PA student survey participants, 17 of the 20 that responded ‘very’ or ‘fairly true for me’ had previous dissection experience, and none with that experience responded negatively. This result contrasted with the 17 PA students who had undergraduate anatomy without cadaveric dissection: 10 responded negatively, and 4 responded ‘somewhat true for me.’ Only three respondents without previous cadaveric dissection experience answered ‘very’ or ‘fairly true for me.’ The dental student data, when sorted by previous cadaveric dissection experience, did not show the same inverse relationship. All six of the dental student survey participants with no cadaveric dissection experience in their undergraduate anatomy course answered the question in the negative, however. Recall that undergraduate anatomy experience data is found in Appendix F.

For question 10 (Table 8), the majority (93%) of survey participants indicated that integrating lab and lecture knowledge into activities would have contributed to their learning (statement 2), with 35% and 37% of participants responding with ‘very’ or ‘fairly true for me.’ For statement 3, the negative wording of ‘I’m not sure how well I understand anatomy’ resulted in 70% students responding ‘not very’ or ‘not at all true for me.’ The last two statements of question 10 asked students to evaluate opportunities for future cadaveric anatomy review.

Figure 9



Note: PA students with cadaveric dissection in an undergraduate anatomy course had far more positive responses that PA students without cadaveric dissection in an undergraduate anatomy course.

Eighty-three percent of students indicated they would like more cadaver review time in future classes, with 64% of participants selecting ‘very’ or ‘fairly true for me.’ Students evaluating statement 5 answered affirmatively; 98% of students felt that reviewing a cadaver in future classes would help them visualize anatomical relationships. Undergraduate anatomy status did not appear to influence student responses to statements 4 or 5.

Survey question 11 was an open response box for additional comments. Responses were not required, and 22 students contributed a written comment. The qualitative data summary is displayed in Table 9. Open coding of the 22 written comments identified 4 codes: anatomical relationships lost, cadaver lab benefit, online disadvantage, and students perceive adequate anatomical knowledge. The first three codes collapsed into one theme: a lack of dimensionality

Table 8

Clinical Anatomy Online Learning Survey Question 10					
Statement 1 Undergraduate cadaveric anatomy contributed to my three-dimensional understanding of a human body in this course.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total (n=60)	19 (32%)	10 (17%)	9 (15%)	2 (3%)	20 (33%)
Dental (n=24)	5 (21%)	4 (17%)	3 (13%)	1 (4%)	11 (46%)
PA (n=36)	14 (39%)	6 (17%)	6 (17%)	1 (3%)	9 (25%)
Statement 2 Activities that integrate lab and lecture knowledge would have contributed to my learning.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	21 (35%)	22 (37%)	13 (21%)	4 (7%)	0 (0%)
Dental	8 (34%)	6 (25%)	8 (34%)	2 (8%)	0 (0%)
PA	13 (36%)	16 (44%)	5 (14%)	2 (6%)	0 (0%)
Statement 3 Regardless of my grade, I'm not sure how well I understand anatomy.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	2 (3%)	5 (8%)	11 (19%)	32 (53%)	10 (17%)
Dental	2 (8%)	2 (8%)	5 (21%)	10 (42%)	5 (21%)
PA	0 (0%)	3 (8%)	6 (17%)	22 (61%)	5 (14%)
Statement 4 I would like cadaveric review lab time in future classes.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	16 (27%)	22 (37%)	12 (20%)	9 (15%)	1 (2%)
Dental	4 (17%)	11 (46%)	5 (21%)	3 (13%)	1 (4%)
PA	12 (33%)	11 (31%)	7 (19%)	6 (17%)	0 (0%)
Statement 5 Reviewing relevant anatomy on a cadaver in future classes would help me visualize anatomical relationships for the whole body.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	23 (38%)	22 (37%)	14 (23%)	0 (0%)	1 (2%)
Dental	9 (37%)	11 (46%)	3 (13%)	0 (0%)	1 (4%)
PA	14 (39%)	11 (31%)	11 (31%)	0 (0%)	0 (0%)

and context inhibits deep learning. The final code and theme were similar: online clinical anatomy provided an adequate learning experience.

The majority of students contributing comments coded as ‘anatomical relationships lost’ participated in an undergraduate anatomy course. One student responded “I’m afraid that I did a ton of memorizing videos and things rather than truly understanding how it all fits together,” while another stated “It was just hard to get the whole picture so many times over the course.” Even though most commenters had taken a previous anatomy course, their statements suggested they struggled with creating a meaningful schema for their learning.

Twelve students’ comments were coded as ‘cadaver lab benefit,’ meaning cadaver lab was perceived as a helpful tool to learn anatomical relationships. “I firmly believe a cadaver would have helped solidify and really tie everything together” was a typical response, similar to “The cadaver would have helped [me] better understand the anatomy and its relationships.” The majority of responders for this code took an undergraduate anatomy course without dissection and were PA students.

For the code ‘adequate anatomical knowledge,’ all of the respondents had participated in an undergraduate anatomy course. One student linked the sufficiency of online clinical anatomy with an effective use of time: “Online was plenty sufficient. Better time to study vs time it takes to dissect and dissect out fat etc.” Whether or not their undergraduate anatomy course included cadaveric dissection did not influence their comments, and commenters were evenly split between PA and dental students. Two-thirds of the commenters coupled the adequacy of online clinical anatomy with an acknowledgement of the unusual circumstances: “given the situation” and “all things considered” or other qualifying statements were common. These results are in contrast to the students whose comments coded as ‘online disadvantage.’ Students with undergraduate anatomy without cadaveric dissection uniformly stated that being online was a disadvantage, as did the commenter with no previous anatomy experience.

Table 9

Qualitative Data Summary: Codes, Definitions, Samples, and Themes.

Codes	Code Definitions	Sample Statements	Themes
Anatomical relationships lost	Recognition of the body as integrated system, acknowledgement of the lack of spatial awareness/context, reliance on rote learning as context is lost.	I found the online anatomy course to be very difficult in understanding how to connect everything together.	Lack of dimensionality and context inhibits deep learning.
Cadaver lab benefit	Acknowledgement of the cadaver as important visual and tactical component of learning anatomy, particularly 3D relationships.	The cadaver would have helped [me] better understand the anatomy and its relationships.	
Online disadvantage	Perception of being online as a barrier to deep learning, lack of 3-dimensionality hindered context, retention.	[T]his course presented online hindered my ability to grasp the subject well.	
Students perceive adequate anatomical knowledge	Perception of sufficiency of knowledge even with unexpected delivery method.	I think my experience was good and sufficient for moving forward to my other courses.	Online clinical anatomy provided an adequate learning experience.

Analysis

Academic Outcomes.

Summative. The means of the students' scores of all assessment items were significantly higher for remote learners than for F2F learners. This is consistent with the body of evidence within education generally supporting online pedagogy as an equitable alternative to face-to-face pedagogy (Moore & Diehl, 2019). Admittedly, the lecture portion of the course changed very little by switching to remote delivery, so it could be argued that summative performance should not have changed, either. The concern (and impetus for the study) lay in that the laboratory is the foundation of formative learning. For Clinical Anatomy, formative learning in a laboratory adds context and authenticity to summative learning as well as low-stakes knowledge evaluation opportunities. It was unknown if significantly altering the delivery method of laboratory content from live small-group facilitation and dissection to remote large-group facilitation and dissection videos would affect students' ability to learn the formative material.

PA students' summative means were significantly higher for the 2020 remote cohort than the 2019 F2F cohort, also. In fact, the significance of the overall results is largely due to the PA students' performance. Dental students also performed better in 2020, but the difference was not significant. One student commented in the survey that (s)he had more time to study due to not having to dissect, and this is a possible explanation for the improved performance in 2020. As noted in chapter 2, time was a rarely controlled variable in studies assessing online learning, and this study is no exception. Another possible explanation is that the groups might have been inherently different despite similarities in demography and undergraduate performance.

As for the Bloom's Taxonomy levels, both low and high assessment items performed better in 2020 than in 2019 but failed to reach significance. Researchers also collapsed the years together and looked at the differences in means between high and low Bloom's level assessment items. While not a comparison of remote versus F2F learning, the differences were significant, indicating the low Bloom's level questions were answered correctly more than the high Bloom's level questions were. These results supported that the classification of questions according to the

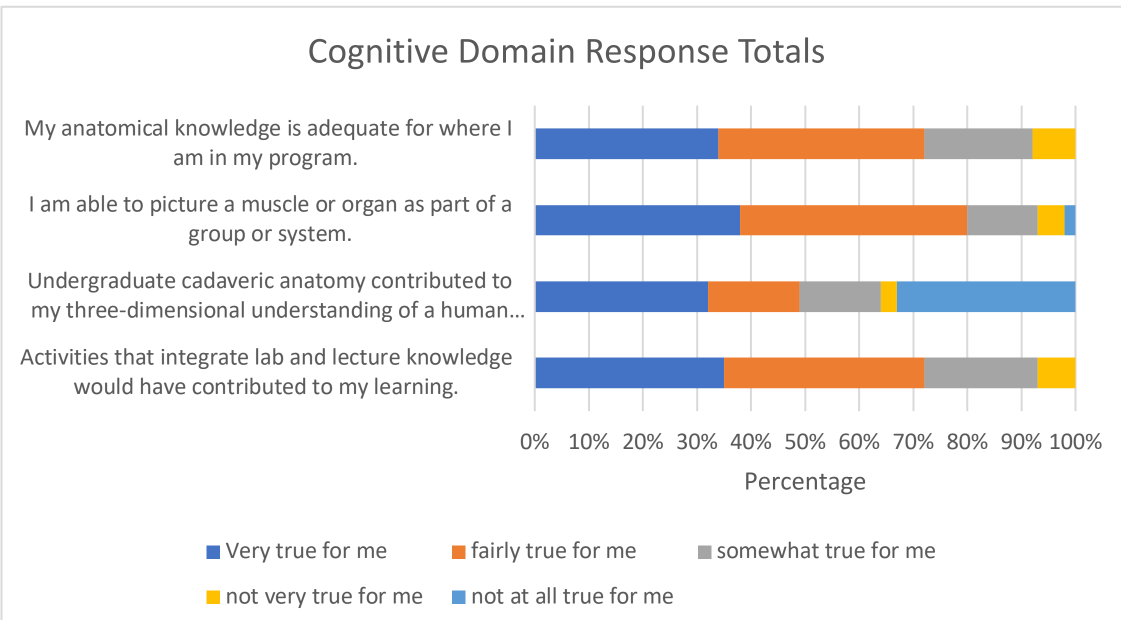
Blooming Anatomy Tool (Thompson & O'Loughlin, 2015) did properly discriminate between levels.

Formative. Students in the 2019 F2F cohort performed better in weeks one and five, corresponding to the lower limb & shoulder, and thoracic & abdominal cavity content. The 2020 remote cohort outperformed the 2019 F2F cohort in weeks two (upper limb), three & four (head & neck), and six (abdominopelvic cavity & perineum). The overall significance of weeks three and five depended upon either PA or dental students as only one program had significant results. The week 1 results could indicate a steep learning curve for students beginning a remote Clinical Anatomy course. Students in the remote cohort had to navigate a completely online system of daily video call links and identification numbers, breakout rooms, online proctoring software, learner management system software, and transactional distance inherent to online learning. The volume of technological changes may have been a larger cognitive load than anticipated and may indicate more support is necessary for students in the beginning of a fully remote/online course. By week 2, the remote cohort differences in means were consistently higher and remained so other than for week 5. Possibly this is due to the previously mentioned suggestion that not dissecting allowed for more study time. Because 2019 was a historical control, it is also possible that the 2020 formative exams were easier in spite of the care taken to follow the same test blueprint. When reviewing the formative exams collectively, the 2020 remote cohort outperformed the 2019 F2F cohort twice as often.

Clinical Anatomy Online Learning Survey. Survey statements were grouped by domain for analysis. There were four statements categorized in the cognitive domain, eight in the psychomotor domain, and four in the affective domain. All percentages are for the total number of students unless otherwise specified. Cognitive domain response totals are found in Figure 10.

With the cognitive domain statements grouped together, the general positivity of student perceptions becomes clear. The first two statements refer to students' anatomical knowledge specifically and exceed 70% agreement when collapsing 'very' and 'fairly true for me.' Including 'somewhat true for me,' a statement intended to be ambivalent but may have been interpreted as weakly positive, and agreement exceeds 90%. Regarding undergraduate cadaveric anatomy (third statement), it should be understood that 25% of the individuals marking 'not at all true for me' did not take anatomy at all.

Figure 10

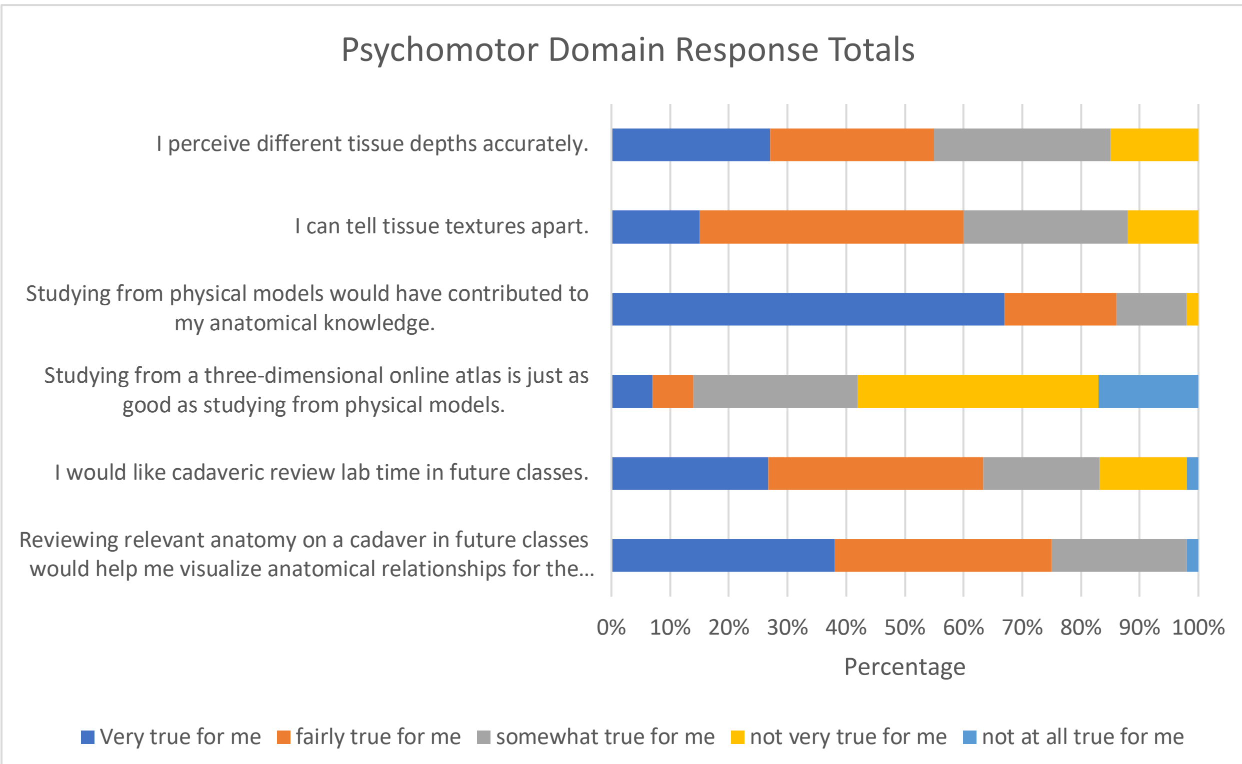


The fourth statement invited student opinion regarding integration activities for lecture and laboratory. Over 70% of students indicated integrated activities would have contributed to their learning. An interesting point regarding this statement: the virtual laboratory groups that met in breakout rooms after lecture were designed to provide a space to review laboratory content *and* to integrate that material into the lecture content. It is possible that faculty need to articulate the purpose more clearly to students and teaching assistants. Additionally, more scaffolding may be needed initially to provide concrete instruction to teaching assistants on the best practices for online integration activities. Due to the remote nature of the 2020 course, teaching assistants and faculty alike were adapting to student needs in real time and concrete activities such as interactive quizzes evolved as the class progressed. The short duration of the course and the daily volume of new material may need to be considered when planning online activities. Though faculty do not want to tailor the content with a reductionist approach, guiding students toward the most relevant material may need to be more explicit when considering the transactional distance inherent to online learning.

Though students participating in the focus group mentioned incomplete and/or surface-level anatomical knowledge, the majority of students indicated a positive perspective regarding the cognitive domain of their learning. This could be due to several factors. It is possible that only a few vocal students felt their knowledge was fragmented or rote, with the remainder of students satisfied. Timing of the focus group and survey could also be a factor. The focus group occurred at the start of the third unit, while the survey was open for two weeks after the course. Emotions could have been more extreme in the midst of the course as opposed to after the course, thus dampening the survey response. Last, a quasi-testing effect could have affected student responses. Students participating in the focus group heard most of the statements that would become the survey and may have responded differently upon reflection. Ultimately, the majority of students regarded their anatomical knowledge positively.

The psychomotor domain response totals, though less emphatic and less consistent than the cognitive domain totals, still represent overall positivity of responses to most statements (Figure 11). The first two statements were designed to evaluate students' perceptions of tissue depths and textures. Depth and texture were discussed in the videos and laboratory review sessions but were unable to be directly observed or felt in the remote course, and both support contextual understanding of lecture content. Over 80% of students felt these statements were 'very' or 'fairly' or 'somewhat true for me.' No students indicated 'not at all true for me' for either statement. These results support the efforts faculty made to discuss tactile knowledge that would typically be determined during cadaveric dissection.

Figure 11



The next two statements evaluated the use of models. Recall that 25% of students purchased a model for their own personal use, and 75% of students felt models should be provided in an online course (Table 7). Approximately 85% of students felt physical models would have helped them to learn. Slightly over 40% of students agreed that online models were just as good as physical models. The difference in response to these two statements provides insight into how some new health professions students perceive the utility of physical models, and this is consistent with the findings discussed in chapter 2 regarding the limitations of online anatomy (Attardi et al., 2016; Davis et al., 2014). It is possible that three-dimensional, physical models provide an easier learning experience, if not an academically superior one for new learners.

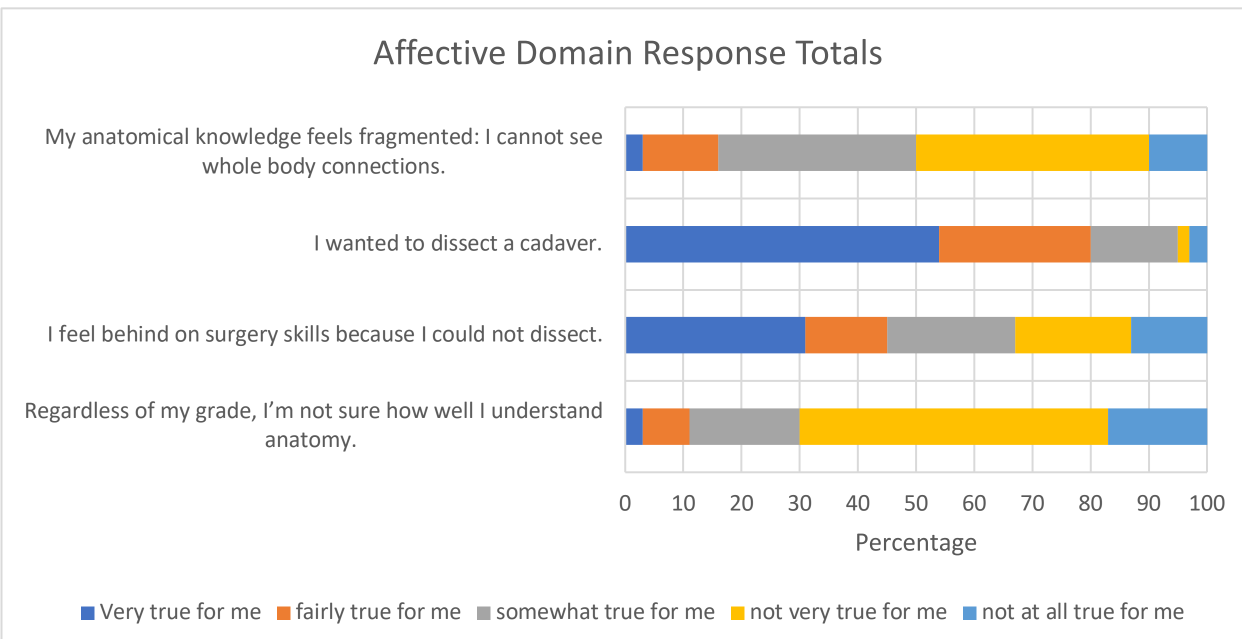
The last two statements pertain to students' preferences regarding future cadaveric review time. Due to the remote nature of the course, most students would prefer a vertically integrated, just-in-time cadaveric review pertinent to their new material. Generally, vertically integrated anatomy review is positively reviewed in the literature (Wijnen-Meijer et al., 2020), and it may be that just-in-time cadaveric reviews would be especially beneficial to remote clinical anatomy students.

The first statement of the affective domain seemed like a negative version of the cognitive domains' 'I am able to picture a muscle or organ as part of a group or system;' however, students did not answer it in the same manner (Figure 12). Approximately half responded negatively to the statement indicating that they did not feel that their knowledge felt fragmented. This is in contrast to the 80% positive response to the cognitive domain statement. More students felt their knowledge was fragmented than felt they could not place an organ or muscle in a group or system. Perhaps the discrepancy observed between the two statements is part of the main conclusion to be drawn from this study. In other words, students largely perceived their learning as appropriate, but many *felt* uneasy about it. Remote learning was new to many students and faculty alike in June of 2020, and it could be that the feelings regarding the new format or remote learning in general affected the assessment of their feelings about their anatomical knowledge.

The last statement was an attempt to ask how they felt about their anatomical knowledge from another perspective. Approximately 30% agreed at least ‘somewhat true for me.’ This result also contrasts somewhat with the ‘I am able to picture a muscle or organ as part of a group or system’ cognitive domain statement. Asking students how they felt about their knowledge consistently yielded less positive results than when students were asked about the knowledge directly.

The middle statements were directed toward their feelings regarding not being able to dissect. The most positively rated statement in the affective domain was ‘I wanted to dissect a cadaver. Students were more divided on feeling behind on surgery skills.

Figure 12



This may be due to the fact that not all dental and PA students want to make surgery their specialty. The possibility also exists, however, that students recognized that a remote 6.5-week course in a two or four year program would not permanently impair their surgery skills.

The open response box provided context for the quantitative portion of the survey. Though students generally rated each domain positively, the response box offered an opportunity for dissenters to articulate explanations and feelings. These statements led to the first three codes and theme: ‘lack of dimensionality and context inhibits deep learning.’ In contrast, the other theme emerging from the qualitative data was ‘Online clinical anatomy provided an adequate learning experience.’ This theme was more consistent with the quantitative portion of the survey and the academic outcomes. It’s possible that the students contributing to the ‘lack of dimensionality and context inhibits deep learning’ theme were also in the minority or outliers in the quantitative survey.

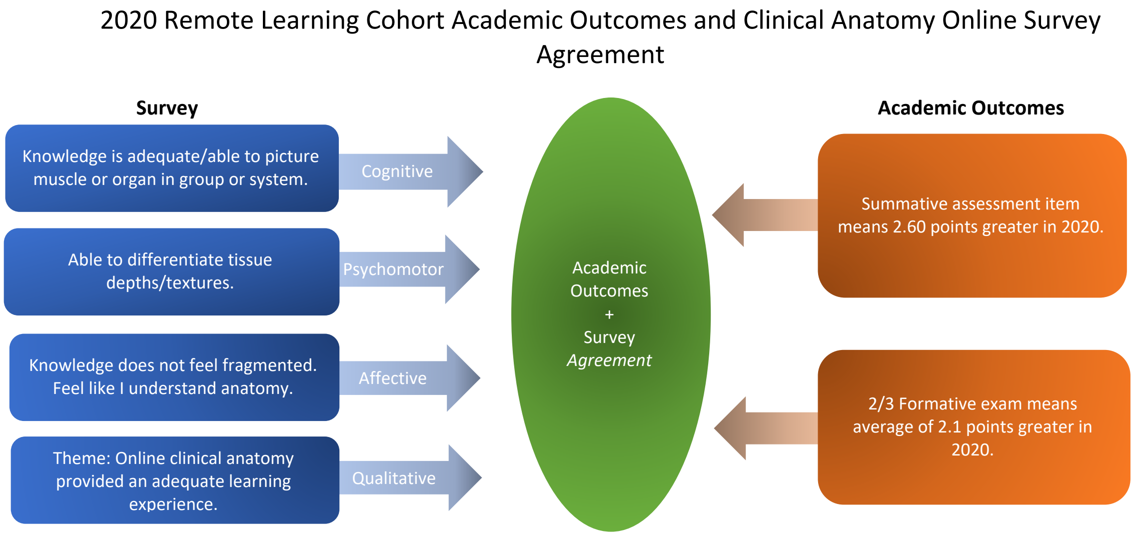
Relationships between Actual and Perceived Knowledge. With the academic outcomes and student perspectives are analyzed, the final step is to determine what, if any, relationships exist between the two. The academic outcomes, or actual knowledge, was fairly uniform: the 2020 remote cohort outperformed the 2019 F2F cohort by 2.60 points on the summative assessment items and the majority of the formative exams (average of 2.1 points greater on 2020 significant exams). The survey of student perspectives, or perceived knowledge, was generally positive but less uniform. Each domain of the survey was evaluated for data most in agreement (Figure 13) or disagreement (Figure 14) with the academic outcomes. Agreement was determined as at least 50% of students responding ‘very true for me’ or ‘fairly true for me.’ ‘Somewhat true for me’ was not included so that the positive and negative responses were assessed with two answer choices each. Disagreement was determined by identifying the highest percentage of negative responses per domain. Disagreement rarely exceeded 50%, so the same criteria was not applied.

Between 70-80% of students felt that their knowledge was adequate for where they were in the program as well as agreed that they could picture a muscle or organ within a group or system. Somewhat surprisingly, 50-60% responded favorably that they could perceive different tissue textures and depths accurately. For the affective domain, approximately 50% of students did not agree that their anatomical knowledge felt fragmented, and this statement was included in the disagreement figure as well. The majority of students disagreed with 'regardless of my grade, I am not sure how well I understand anatomy.' Enough students wrote comments stating or describing the sufficiency of online Clinical Anatomy that a code and theme emerged even though it was less frequently described than other codes and subsequent theme. In light of the superior academic outcomes for the 2020 remote cohort, the positivity and support from each survey domain and method indicated that at least a slim majority of students' perceptions were in agreement with their academic outcomes.

A significant minority of students' perceptions were in disagreement with the academic outcomes (Figure 14). For the cognitive domain, the highest percentage of disagreement (even after removing the students who had not taken undergraduate anatomy) was with the statement 'undergraduate cadaveric anatomy contributed to my three-dimensional understanding of a human body in this course.' Since the statement referred to how much their undergraduate course contributed to their ability to see the three-dimensionality of the human body and not the current course, it was excluded from this discussion. The remainder of responses were less than 10% negative, so the cognitive domain was excluded from the disagreement analysis.

The psychomotor domain statements most in disagreement with the academic outcomes regarded models. Between 80-90% of students indicated that physical models would have helped them study, and 78% felt models should have been provided by the university. Over 50% did not agree that online three-dimensional models were as good as physical models. These results reflected a perceived lack of tactile learning opportunities for this course. Approximately 50% of

Figure 13

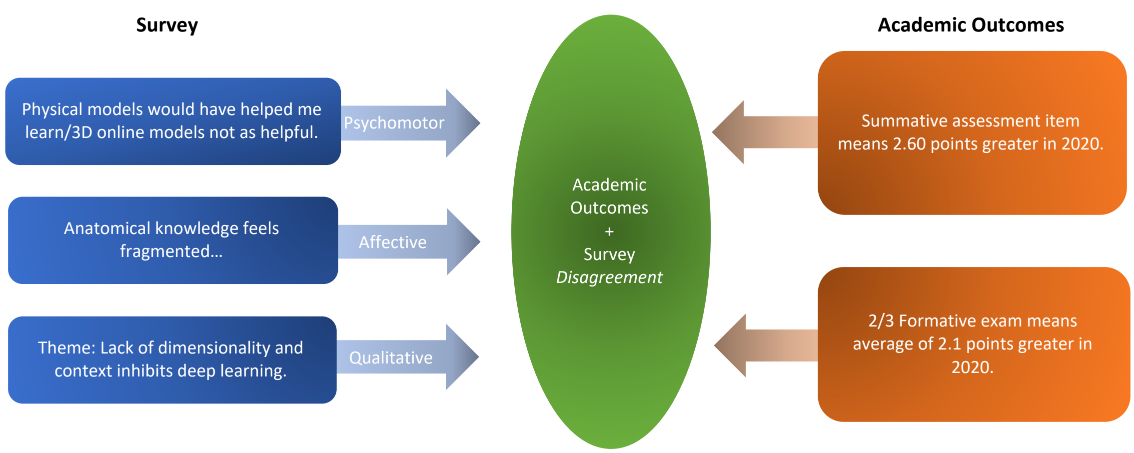


Note: Survey selections represent 50% or greater of students responding 'very true for me' or 'fairly true for me.' See Figures 11-13 for cognitive, psychomotor, and affective domain results. See Table 9 for qualitative results. See Tables 3 and 4 for summative assessment items and formative exams statistical analysis.

students indicated that their anatomical knowledge felt fragmented and that they could not see whole body connections, which is in contrast to both the cognitive domain survey results as well as the academic outcomes. The theme, 'lack of dimensionality and context inhibits deep learning,' supported the findings of the psychomotor domain regarding students' desire for physical models. The theme could also explain the discrepancy between the cognitive and affective domain as well as the disagreement between the affective domain and the academic outcomes. Students may perceive that 3-dimensional, tactile learning is essential to deep learning, this could account for the feelings of fragmented anatomical knowledge. It is also possible that students perceive their anatomical knowledge (cognitive domain) as sufficient for

Figure 14

2020 Remote Learning Cohort Academic Outcomes and Clinical Anatomy Online Survey Disagreement



Note: Survey selections represent the highest percentage of students responding 'not very true for me' or not at all true for me.' See Figures 11-13 for cognitive, psychomotor, and affective domain results. See Table 9 for qualitative results. See Tables 3 and 4 for summative assessment items and formative exams statistical analysis.

multiple choice or fill-in-the-blank exams, as these types of assessment questions typically do not exceed the 'analyze' level of Bloom's Taxonomy for this course.

Conclusions

The 2020 remote cohort had higher academic outcomes on summative assessment items than the 2019 F2F cohort. When separated by program, the PA students' means were significantly higher than the PA students from 2019, but the dental students' means were not.

Bloom's level of question difficulty was not affected by remote delivery. The 2020 remote cohort had higher academic outcomes on the majority of formative exams after week 1.

The Clinical Anatomy Online Survey results were generally positive. The cognitive domain statements garnered the highest percentages of positive responses, and portions of the psychomotor and affective domains garnered the lowest. Qualitative responses supported both the high cognitive domain responses and the lower psychomotor/affective domain responses. The overall results of the survey indicated students perceived their anatomical cognition as adequate but would prefer psychomotor domain supports like physical models in lieu of cadavers for fully online Clinical Anatomy. The affective domain statement responses regarding students' feelings about their anatomical knowledge varied.

Relationships between actual and perceived anatomical knowledge fell into two dichotomous categories of agreement and disagreement. The cognitive survey statements were highly positive indicating agreement with the academic outcomes. Alternatively, psychomotor and affective domain responses were both in agreement and disagreement with academic outcomes. The following chapter will provide a discussion of these results. Key findings will be stated and situated within the literature, and a discussion of what the results mean within a Clinical Anatomy classroom and for anatomy education will follow. Chapter five will conclude with a discussion of future research and implications.

Chapter 5: Discussion

This final chapter will include a discussion of the two major findings from this research study. The findings were analyzed according to Bloom's Domains of Learning. Bloom's Domains are education models for three different modes of learning: cognitive, psychomotor, and affective. The limitations of the study follow. Looking toward the future, the last two sections of this chapter include implications for educators and future research. The remainder of the introduction is a review of this study.

The COVID-19 pandemic forced educators worldwide to adopt online learning pedagogy. In a rapidly evolving situation, distance learning is called emergency remote teaching (ERT), and the major discriminating factor between online learning and emergency remote teaching is the time available for planning. Online learning pedagogy has established best practices that promote student learning, and educators spend months to years preparing an online course (Reyna, 2020). Due to the unpredictability of emergencies, ERT typically adapts in-class instruction to an online format rapidly within a few weeks or months (Hodges et al., 2020; Rapanta et al., 2020). Educators have little time to adjust content delivery or course structure to best support online learning. More typically, the course is taught as it was face-to-face (F2F), and both students and faculty adjust as best as possible.

At the University of Oklahoma Health Sciences Center, anatomy educators adapted their F2F Clinical Anatomy course to a digital format by creating videos and review sessions to replace cadaveric dissection. Digital images were used to create weekly laboratory practical exams in keeping with the tagged cadaver exams used in the F2F course. Reconstructing the laboratory in a digital format allowed faculty to maintain the same course and session objectives for the remote course.

One purpose of this research study was to evaluate the academic outcomes of the remote course. Laboratory videos, online review sessions and digital image exams were a very different experience from in-person cadaveric dissection, and the effects of such a change in a Clinical Anatomy program were largely unknown. A survey of student perspectives was administered to remote learners as well. The purpose of the survey was to include students' thoughts and opinions regarding their anatomical knowledge. Finally, researchers analyzed both the academic outcomes and the student perspectives to determine what, if any, relationships existed in the data. The research questions below reflect the purpose descriptions.

1a. Do clinical anatomy academic outcomes of PA and dental students differ between remote and face-to-face learners?
1b. If so, how do the academic outcomes differ?

2. How do PA and dental students perceive their anatomical knowledge upon completion of a remote, synchronous Clinical Anatomy course?

3. To what extent do PA and dental student perceptions of anatomical knowledge relate to their academic outcomes?

To investigate these questions, researchers analyzed summative and formative exam questions administered to a F2F cohort in 2019 and a remote cohort in 2020. The summative questions were identical, and the formative exams were created according to the same test blueprint. A semi-structured student focus group session provided information used to create a student perspectives survey. The voluntary survey was administered at the end of the 2020 remote course.

Emergency remote teaching provided an adequate Clinical Anatomy learning experience. To assess the cognitive domain, or the knowledge acquired by students, summative assessment items and formative exams were statistically analyzed. Summative assessment item scores for the remote cohort were significantly higher than the face-to-face (F2F) cohort, with a small but significant effect size. Formative exams were significantly higher as well, but the effect size indicated the difference was negligible. The academic outcomes indicate that achievement on exams did not suffer because of ERT. The cognitive domain was assessed by students in the Clinical Anatomy Online Survey, with a large majority of students perceiving their knowledge as adequate for a first-year student. This was supported qualitatively with some students commenting that they knew enough anatomy to move onto other coursework, though this was often qualified with an acknowledgement of the pandemic's role in limiting educational options.

Limpach et al. suggested a similar outcome for a fully online anatomy course for pharmacy students; online students scored the same or slightly better than historical F2F students (2008). Attardi et al. reported no difference in scores in a fully online undergraduate course as well (2018). In a meta-analysis of over 50 cohorts (many of these health professions), the effect size for online learning was negligible, indicating online students did no better than F2F students (Means et al., 2013) Further comparisons can only be made with blended or flipped classroom research as no other known fully online anatomy research reported academic outcomes.

Several blended learning/flipped classroom research studies also indicated no difference in scores for anatomy courses (R. A. Green & Whitburn, 2016; Nieder & Borges, 2012; White et al., 2019). In a broad systematic review of flipped classroom research in medical education, Chen and colleagues showed that for anatomy courses there were negligible differences in flipped versus F2F performance. Other studies exhibited modest gains in some categories of knowledge. In another systematic meta-analysis of flipped classrooms, Evans determined most courses had at least one significantly improved academic outcome, but the overall results were not significant (2019). Morton and Colbert-Getz found assessment items classified as Bloom's cognitive level 'analyze' did result in modest gains in a flipped classroom scenario (2017). The most significant outcome found for a health professions anatomy course was in a flipped classroom for Doctor of Physical Therapy students. High Bloom's assessment items' means were significantly higher with a large effect size (Day, 2018).

Compared to fully online anatomy courses, the present research study yielded positive results in that the overall summative assessment items were statistically significant and had a small, significant effect size. Other comparisons are limited due to the differences between fully online and blended learning/flipped classrooms; however, the present study yielded more significant data than many of the blended learning studies. This is highlighted in comparing the present study to the Means et al. (2013) meta-analysis. In that large, multi-cohort study, blended learning had an effect size of $d = 0.35$, while fully online learning had an effect size of $d = 0.05$. The present study, with an effect size of $d = 0.29$, is far closer to the blended learning effect size, indicating a degree of success more in keeping with blending learning models than with fully online models.

Ultimately, the statistical analysis of this study indicated that the amount of anatomical knowledge that students could demonstrate remotely was slightly greater than what the F2F students obtained. These results support the assertion that the relationship between students and content was definitely not negatively impacted due to transactional distance (Moore, 2019). The students' positive responses to the cognitive domain statements further support this interpretation.

The psychomotor and affective domains were also addressed in the survey, with some data supporting the adequacy of remote learning. The psychomotor domain was of particular interest as cadaveric dissection was a central feature of F2F learning. The psychomotor domain, originally conceived as skill acquisition (such as introductory scalpel skills), was expanded by

Harrow (1972) to include any knowledge obtained via neuromuscular coordination. According to Harrow, knowledge classified within the psychomotor/physical domain could merely augment or support cognitive knowledge; no skill-building required. This corresponds to one main purpose of cadaveric dissection, namely the provision of context, authenticity, and dimensionality to the cognitive domain content. From the current survey data, a slim majority of students felt they could differentiate tissues and textures, and half of the students did not feel that their anatomical knowledge was fragmented. These results indicate the adequacy of online Clinical Anatomy for some PA and dental students.

The literature regarding the psychomotor and affective domain generally does not support the adequacy of fully online clinical anatomy. Multiple studies reported students' indicating a preference for laboratory over online or text materials (Attardi et al., 2016; Barbagallo et al., 2020; Davis et al., 2014). Only a third of first year medical students used e-learning materials when given the opportunity, and an overwhelming majority agreed that 'seeing specimens is essential to understanding anatomy' in a survey of anatomy teaching preferences (Davis et al., 2014). Kelsey (2020) found that a lack of specimens made learning seem more difficult for non-clinical graduate students. When Attardi (2018) provided more structure to a fully online undergraduate anatomy course, student responses toward online laboratory improved but did not exceed F2F responses. In the 2018 iteration, Attardi provided faculty-moderated small-group breakout rooms; more scaffolding ameliorated negative comments from students regarding their laboratory experience. Pandemic-era studies of student perspectives found similar results: lecture was just as good online, but laboratory was lacking (Cuschieri & Calleja Agius, 2020).

Faculty surveys do not provide an argument for online clinical anatomy, either. Early in the pandemic, surveyed faculty responded that a lack of cadaveric exposure/practical sessions was a weakness of remote learning (Longhurst et al., 2020). Prior to the pandemic, 100% of responding anatomy educators used cadaveric dissection to teach their courses (McBride & Drake, 2018), suggesting their perceived necessity in achieving learning objectives. Authentic clinical applications are featured in cadaveric dissection as each donor brings an open-ended experience and exploration to the laboratory. Additionally, the context and dimensionality provided by the cadaver frame the cognitive domain knowledge in a concrete physical donor. When the faculty at OUHSC created the laboratory dissection videos, they were careful to include context such as dissection cues about layers, textures, and depth as well as an overview of the steps of the dissection. These cues and summaries may be sufficient for their clinical anatomy experience. For half of the current survey participants, the video/laboratory sessions/lecture combination was sufficient for adequate anatomical knowledge cognitive gains and for their anatomical knowledge not to feel fragmented. The possibility also exists that students are responding to 'pandemic' surveys with full knowledge of the limitations imposed by the pandemic (D. J. R. Evans & Pawlina, 2021) and are adjusting their responses accordingly.

Students perceived the absence of physical/tactile experiences as a lost learning opportunity. Some students perceived the psychomotor and affective domains quite differently. A theme emerged from written comments that the lack of 3-dimensionality and context inhibited students' deep learning. The codes that developed this theme referred to the benefits of cadaveric dissection, the loss of anatomical relationships, and the disadvantages of being online. A large majority (98%) felt a physical model would have helped them to study, and nearly 60% of students disagreed that an online atlas was just as good as a physical model. These statements suggest almost all students desired a tangible, tactile experience for clinical anatomy, and the online laboratory experience could not adequately replace it for many students. Students also wanted just-in-time cadaveric review time prior to more advanced coursework and believed such a review would help them to be prepared for future coursework.

The negative responses to the statement ‘activities integrating lab and lecture knowledge would have contributed to my learning’ potentially indicated a suboptimal relationship between the structure, dialogue, and autonomy of the course (Peters, 1998). Simonson also wrote that students require intentional interaction when engaged in online learning: the default of passive reception of knowledge will not suffice (2019). Moore noted that when first moving a course online, there is often a need to adjust the relationship between the learner and content (1989).

Faculty traditionally relied on cadaveric dissection laboratory to increase dialogue and provide teachable moments to students. The open-ended, exploratory, tactile, active nature of cadaveric dissection met those needs. Though faculty had prepared an online laboratory digital library and review sessions tailored to meet students’ active learning needs, many students clearly indicated a desire for physical learning, even as the cognitive needs were being met. This is consistent with a meta-analysis indicating laboratory modality (including digital) is irrelevant to academic outcomes, but that students and faculty alike perceive cadaveric dissection as preferable (Wilson et al., 2018). Covid-19 pandemic-era survey research of students participating in remote Clinical Anatomy also indicated students felt that F2F clinical anatomy would have been preferable to their remote learning experience (Cuschieri & Calleja Agius, 2020; Shahrvini et al., 2021). For the present study, the lack of psychomotor learning might be the reason that half of students felt their anatomical knowledge was fragmented. Many students were influenced to apply to OUHSC by the opportunity to participate in cadaveric dissection, and the majority wanted to dissect a cadaver in Clinical Anatomy. These survey results indicate the significance of cadaveric dissection to PA and dental students.

The literature largely supports psychomotor and affective domain learning objectives derived from cadaveric dissection, even if framed in a different language. Multiple surveys establish the students' desire and/or appreciation for cadaveric dissection, indicating a persistent student preference (Attardi et al., 2016; Barbagallo et al., 2020; Cuschieri & Calleja Agius, 2020; Davis et al., 2014; Flack & Nicholson, 2018; Shahrvini et al., 2021). In these studies, cadaveric dissection was most referred to as supporting the cognitive domain. Beyond supporting the cognitive domain, the psychomotor and affective domains facilitate the development of professionalism and NTDIS (D. J. R. Evans et al., 2018; Flack & Nicholson, 2018). Cadaveric dissection provides a space for cognitive apprenticeships that expose students to the ethics and mannerisms of a clinician. Cadavers are often referred to as students' 'first patients,' and faculty members mentor the proper ethics and relationship between clinician and patient (Rizzolo & Stewart, 2006). Team communication, peer-teaching, and self-assessment are considered essential skills for new health professions students to develop into clinicians (Flack & Nicholson, 2018; Maloney et al., 2021). A group goal of a well-attempted, complete dissection requires physical skill development (psychomotor domain) and collaboration (affective domain); however, support of the cognitive domain is only the immediate benefit. The NTDIS and professionalism development that cadaveric dissection laboratory provides introduces to students to attitudes and perspectives that change the way they view patients as well as themselves (Stephens et al., 2019). Cadaveric dissection initiates the process of developing a clinician's habits of mind.

Limitations

As with all research, there are caveats to these findings. The quasi-experimental nature of the academic outcomes investigation relied upon a historical control. It's possible that even though the cohorts were similar there was an undetected difference that accounted for the positive results. Ideally, repeating this analysis with more fully online dental and PA students would strengthen the outcome. The survey was constructed in real time and only administered to one cohort. This limits the generalizability of these findings, even though other literature supports the results. There were no survey responses for the 2019 F2F cohort, and so it remains unknown if the remote and F2F students' perceptions would have been different.

Time spent studying was not measured. Multiple studies reference students indicating that online learning, fully or blended, required more study time (Green & Whitburn, 2016; Means et al., 2013, White et al., 2019). In this study, a student commented that not having to dissect allowed more time for studying. Time is an uncontrolled variable and could be part of the reason the present study yielded significant results.

The course format changed slightly between 2019 and 2020. Though only identical questions were used to assess both cohorts, the remote cohort took a 'mini-summative' quiz prior to the 3 summative exams, and the quiz may have had a positive effect on remote students by lowering first exam anxiety prior to their unit 1 exam.

As mentioned in chapter 3, the COVID-19 pandemic remains an unquantified covariate. The extent to which the pandemic influenced the remote cohorts' ability to perform academically or their survey responses remains unknown. All 'pandemic' research, particularly student perspectives studies, should be read with this covariate in mind (D. J. R. Evans & Pawlina, 2021). Even with the limitations inherent to this study, there are positives to consider moving forward.

Implications for Anatomy Education

Currently, there is a real fear among anatomy educators that positive academic outcomes resulting from remote learning, such as this study, will be used as justification to cut cadaveric dissection from clinical anatomy programs (Evans & Pawlina, 2021; Jones, 2021; Maloney et al., 2021). Cadaveric dissection, though preferred by students and considered essential by many anatomy educators, was recently found to be the most expensive laboratory modality (Chumbley et al., 2021). As health professions administrators evaluate the finances associated with dissection, they could perceive the cost-to-benefit ratio as being too high in light of sufficient academic outcomes. Anatomy educators are currently being cautioned to be prepared for a detailed cost-to-benefit justification for the inclusion of cadaveric dissection (D. J. R. Evans & Pawlina, 2021; Maloney et al., 2021).

This situation points to a larger problem. Currently, pre-clinical cognitive domain knowledge is frequently assessed in a similar format as high-stakes testing such as licensing exams in order to promote student success on those exams. Additionally, in the attempt to quantify knowledge gains in health professions courses, researchers necessarily avoid knowledge gained in currently unquantified ways. As a result, 'academic outcomes' is only an approximation or a representation of what students actually learn, and the present study is no exception. If administrators only use measurable academic outcomes to determine what materials are available to students, the possibility exists of losing the means to teach the unquantified curriculum. In the context of the present study, this would mean the psychomotor and affective domain knowledge could be marginalized or eliminated. In the larger context of anatomy education research, it could mean NTDIS and initial professionalism skills and attitudes might not be taught in clinical anatomy. This is not to say that costs should not be considered and knowledge should not be quantified. But what is essential is to resist the reductionist mindset that quantifiable academic outcomes tell the entire story of what students learn. Using academic outcomes as the primary determinant of course or program resources may be an invalid use of those outcomes.

For the anatomy educator, converting the open-ended, exploratory nature of cadaveric laboratory to a digital format can be difficult. The cognitive knowledge can be accounted for by finding a good image or video, but the teachable moments that emerge from anatomical anomalies or evidence of surgery or illness are more difficult to reproduce. It could be that emergency remote teaching accounted for the appropriate transfer of cognitive knowledge, but for transitioning from remote to fully online clinical anatomy educators will have to capture some of the exploratory nature inherent to dissection. This could be done in the format of interactive, introductory case studies that include the basics of imaging or some other format that scaffolds introductory imaging modalities with anatomical knowledge. Research has been devoted to the development of supplemental online materials at the clinical student level. Perhaps the concepts utilized by clinical professors could be adapted for pre-clinical use. It is possible that fully online clinical anatomy will continue to exist in some schools, and the body of research emerging from 'pandemic research' can help establish best practices for those endeavors.

The bulk of anatomy educators will likely sort through the 'pandemic research' for best practices that both students and faculty preferred. Newly created dissection videos could become the pre-lab for dissection instead of a close reading of the dissection manual, and successful online materials could be incorporated into F2F courses to expand modalities of learning. For those educators who wish to keep the lecture + laboratory format, yet modernize aspects of the delivery, the forthcoming body of literature will undoubtedly provide multiple examples of successful implementation.

Future Research

This study highlighted the roles of the laboratory in the cognitive, psychomotor, and affective domains. Though research exists for the laboratory supporting cognitive gains, developing NTDIS, and mentoring the adoption of proper ethical attitudes and judgments of clinicians, the analysis of laboratory within an educational theoretical framework further elucidated the fullness of the contributions that cadaveric dissection laboratory makes to a clinical anatomy course. This study and others support that many students and faculty alike feel that cadaveric dissection adds to students' experiences.

A deep qualitative exploration of *how* cadaveric dissection laboratory promotes cognitive gains, NTDIS, and professionalism would be an asset to anatomy education. Educators recognize these as beneficial outcomes of cadaveric dissection laboratory, but not much is known regarding the processes by which these experiences are formed. A qualitative study of student experiences during laboratory potentially improves anatomy education in 5 ways. First, developing a model or models of the processes required to facilitate cognitive gains, NTDIS, and professionalism validates present observational data supporting cadaveric dissection outcomes. Second, process model(s) supports anatomy educators in demonstrating the value of dissection to administrators. Third, understanding the processes in which students are engaged allows anatomy educators to optimize dissection/laboratory practices for the most benefit. Fourth, anatomy educators creating an online version of clinical anatomy could adapt process models to an online format for a potentially more fulfilling online experience. Fifth, by illuminating process model(s), researchers may determine a way to quantify previously unquantifiable learning via survey development, rubrics, or other assessments. Essentially, understanding how these processes develop potentially allows anatomy educators the ability to maximize, explain, or adapt the cognitive gains, non-traditional discipline-independent skills, and professional ethics and attitudes developed in the laboratory.

Conclusions

First do no harm. This research study demonstrated that remote Clinical Anatomy was an adequate learning experience for many students. This finding indicated that emergency remote teaching of Clinical Anatomy sufficiently met the ethical obligation of providing equivalent learning opportunities to remote learners (Evans, 2018). The results also indicated that many students perceived a learning deficit due to the lack of hands-on, physical learning opportunities. These seemingly oppositional results are potentially explained by classifying learning by Bloom's Domains. Many students were able to discern a lack of psychomotor and affective domain learning even as their cognitive needs were being met.

The results of this study highlight an issue germane to medical education. When assessing academic outcomes, the tendency in pre-clinical medical education is to focus on quantifiable data, which is frequently cognitive domain knowledge. Doing so potentially reduces the value of knowledge gained from the psychomotor and affective domains when administrators have to make budgetary decisions. To effectively demonstrate the value of psychomotor and affective domain knowledge in clinical anatomy, research should be conducted to elucidate the processes in which students engage during cadaveric dissection to develop cognitive gains, non-traditional discipline independent skills, and professional attitudes and mannerisms. With process models to support student and faculty perceptions, researchers may be able to amplify the utility of knowledge gained in underrepresented domains. A concrete understanding of how psychomotor and affective domain knowledge is acquired potentially helps educators and other stakeholders to make more fully informed decisions regarding the pre-clinical curriculum.

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Appendix A

Blooming Anatomy Tool (BAT)

The Blooming Anatomy Tool

Bloom's level	Lower order Level 1 (Knowledge)	Level 2 (Comprehension)	Higher order Level 3 (Application)	Level 4 (Analysis)
Distinguishing features of questions	• Questions are straight forward with answers likely stated verbatim in notes or text • Questions usually not placed in a clinical context • Students not required to make independent connections from the information		• Anatomic information may be placed in a clinical scenario or a new setting (although not all clinical questions are higher order) • Students must interpret and make independent connections from the information	
Key Skills Assessed	Identify, repeat, recall, memorize	Describe or distinguish	Infer or predict	In addition to infer or predict, interpret, judge, critique, or analyze
Types of anatomical information assessed	• Basic Definitions • Facts • Straightforward recall	• Anatomical concepts • Basic special organization • Basic understanding of pathways, blood	• Interaction between 2 or more body systems • Functional aspects of anatomical features beyond*	• Interaction between two or more body systems and applying information to a potentially new situation • Interpretation of anatomical images • Potential to use clinical judgement

Thompson & O'Loughlin, 2015

Appendix B

Online Clinical Anatomy Student Survey

Start of Block: Default Question Block

Q2 Dental and PA Students-thank you so much for taking this survey. Please select the response that best represents you/your opinion for each statement. There are open response boxes at the end of every section if you wish to add more detail to your answers. There is an additional open response box for anything you want us to know at the end of the survey. We appreciate this-you are helping us make online Clinical Anatomy better!

Page Break

Q3 Choose one.

- I am a dental student.
- I am a PA student.

Q4 Choose one.

- I completed an undergraduate anatomy course with cadaveric dissection.
- I completed an undergraduate anatomy course without cadaveric dissection.
- I did not complete an undergraduate anatomy course.

Q5 Choose one.

- Ability to participate in cadaveric dissection enhanced my interest in applying to OUHSC.
- Ability to participate in cadaveric dissection did not enhance my interest in applying to OUHSC.

Page Break

Q6 Please select the response that best represents you/your opinion for each statement.

	Not at all true for me	Not very true for me	Somewhat true for me	Fairly true for me	Very true for me
My anatomical knowledge is adequate for where I am in my program.	•	•	•	•	•
My anatomical knowledge feels fragmented: I cannot see whole body connections.	•	•	•	•	•
I am able to picture a muscle or organ as part of a group or system.	•	•	•	•	•
I perceive different tissue depths accurately.	•	•	•	•	•
I can tell tissue textures apart.	•	•	•	•	•

Page Break

Q7 Please select the response that best represents you/your opinion for each statement.

	Not at all true for me	Not very true for me	Somewhat true for me	Fairly true for me	Very true for me	Not applicable
I wanted to dissect a cadaver.	•	•	•	•	•	•
I feel behind on surgery skills because I could not dissect.	•	•	•	•	•	•
Studying from physical models would have contributed to my anatomical knowledge.	•	•	•	•	•	•
Studying from a three-dimensional online atlas is just as good as studying from physical models.	•	•	•	•	•	•

Q8 I bought my own model(s) for this course.

- Yes
- No

Q9 Models should be provided by the university for online laboratory courses.

- Yes
- No

Page Break

Q10 Please select the response that best represents you/your opinion for each statement.

	Not true at all for me	Not very true for me	Somewhat true for me	Fairly true for me	Very true for me
Undergraduate cadaveric anatomy contributed to my three-dimensional understanding of a human body in this course.	•	•	•	•	•
Activities that integrate lab and lecture knowledge would have contributed to my learning.	•	•	•	•	•
Regardless of my grade, I'm not sure how well I understand anatomy.	•	•	•	•	•
I would like cadaveric review lab time in future classes.	•	•	•	•	•
Reviewing relevant anatomy on a cadaver in future classes would help me visualize anatomical relationships for the whole body.	•	•	•	•	•

Q11 Please record any comments regarding your feelings about your understanding of anatomy here.

____

Page Break

Appendix C

Summative Equality of Variance Data

Summative Assessment Items F-Test Summary					
Category	Equality of Variances Method Folded F	Num DF	Den DF	F Value	Pr > F
Year Overall		101	103	1.44	0.0682
Dental		52	55	1.54	0.1136
PA		48	47	1.01	0.9731
Bloom's High		31	31	1.41	0.3427
Bloom's Low	Pooled	66	66	1.52	0.0922
High_Low Dental		108	108	1.65	0.0099
High_Low PA	Satterthwaite	96	96	1.95	0.0012

Appendix D

Summative Test Statistics

Summative Assessment Items Table Summary								
Category	Year	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
Year Overall	2019		78.4808	76.889	80.0725	8.1847	7.2034	9.478
	2020		81.0784	79.1512	83.0056	9.8118	8.6252	11.3798
	Difference 2019-2020	**Pooled**	-2.5977	-5.0779	-0.1174	9.027	8.2296	9.9969
	Difference 2019-2020	Satterthwaite	-2.5977	-5.0828	-0.1125			
Dental	Year	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
	2019		77.75	75.4838	80.0162	8.4622	7.1343	10.4022
	2020		78.0943	75.1953	80.9934	10.5179	8.8282	13.0135
	Difference 2019-2020	**Pooled**	-0.3443		3.2711	9.5168	8.3947	10.988
	Difference 2019-2020	Satterthwaite			3.2957			
PA	Year	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
	2019		79.3333	77.0538	81.6129	7.8506	6.5353	9.8335
	2020		84.3061	82.0397	86.5725	7.8904	6.58	9.8575
	Difference 2019-2020	**Pooled**	-4.9728	-8.146	-1.7996	7.8707	6.8931	9.174
	Difference 2019-2020	Satterthwaite	-4.9728	-8.1458	-1.7998			
Bloom's High	Year	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
	2019		76.2188	69.6598	82.7777	18.192	14.5846	24.186
	2020		79.75	74.2287	85.2713	15.3139	12.2772	20.3595
	Difference 2019-2020	**Pooled**	-3.5313	-11.9343	4.8718	16.8147	14.3058	20.399
	Difference 2019-2020	Satterthwaite	-3.5313	-11.9391	4.8766			
Bloom's Low	Year	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
	2019		82.806	79.3452	86.2668	14.1884	12.1267	17.1012
	2020		85.3433	82.5346	88.152	11.5149	9.8417	13.8789
	Difference 2019-2020	**Pooled**	-2.5373	-6.9532	1.8786	12.921	11.5326	14.6924
	Difference 2019-2020	Satterthwaite	-2.5373	-6.955	1.8803			
High_Low Dental	Year	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
	High		74.5413	72.2924	76.7902	11.845	10.4541	13.6662
	Low		80.6929	78.9413	82.4445	9.2259	8.1425	10.6444
	Difference High-Low	Pooled	-6.1516	-8.9861	-3.3171	10.6165	9.7028	11.7217
	Difference High-Low	**Satterthwaite**	-6.1516	-8.987	-3.3162			
High_Low PA	Year	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
	High		78.7371	76.5017	80.9725	11.0912	9.7198	12.9166
	Low		84.5515	82.9497	86.1533	7.9477	6.965	9.2558
	Difference High-Low	Pooled	-5.8144	-8.5469	-3.0818	9.6483	8.7722	10.7203
	Difference High-Low	**Satterthwaite**	-5.8144	-8.5487	-3.08			

Appendix E

Formative Exams Equality of Variance Data

Formative Exam F Test Results

	Mean		df		F-test Comparison		
Sample	2019	2020	2019	2020	F	fcritical	Variance
Overall					f < fcritical *significance		
Week 1	26.3341346	22.980198	103	100	3.39	1.39	not equal
Week 2	21.5336538	25.1470588	103	101	1.06	1.39	equal
Week 3	26.7211538	27.5686275	103	101	1.166	1.39	equal
Week 4	22.8932039	25.3970588	102	101	1.02	1.39	equal
Week 5	26.7794118	25.2058824	101	101	2.65	1.39	not equal
Week 6	22.8932039	25.3970588	102	101	1.02	1.39	equal
Dental							
Week 1	25.53125	21.7924528	55	52	3.55	1.57	not equal
Week 2	21.2589286	24.2924528	55	52	1.15	1.57	equal
Week 3	26.6517857	26.6792453	55	52	1.7	1.57	not equal
Week 4	23.3214286	24.8584906	55	52	1.12	1.57	equal
Week 5	26.4537037	24.0849057	53	52	3.53	1.58	not equal
Week 6	22.3482143	24.2641509	55	52	1.09	1.58	equal
PA							
Week 1	27.2708333	24.2755102	47	48	3.45	1.62	not equal
Week 2	21.8541667	26.0714286	47	48	1.6	1.62	equal
Week 3	26.8020833	28.5306122	47	48	2.54	1.62	not equal
Week 4	24.8125	26.0816327	47	48	1.18	1.62	equal
Week 5	27.1458333	26.4183673	47	48	1.39	1.62	equal
Week 6	23.5425532	26.622449	46	48	1.14	1.62	equal

Appendix F

Unabridged Clinical Anatomy Survey Results

Clinical Anatomy Online Learning Survey

Program	Undergraduate Anatomy Status			Dissection enhanced interest in applying	
	cadaveric dissection	no cadaveric dissection	none	yes	no
Dental (n=24)	6	11	7	10	14
PA (n=36)	19	17	0	29	6

Clinical Anatomy Online Learning Survey Question 6

Q6 Statement 1 My anatomical knowledge is adequate for where I am in my program.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total (n=60)	20 (34%)	23 (38%)	12 (20%)	5 (8%)	0 (0%)
Dental (n=24)	8 (33%)	8 (33%)	5 (21%)	3 (13%)	0 (0%)
Dental -no undgrad anatomy	2	3	1	1	0
Dental -yes undergrad anatomy	6	5	4	2	0
PA (n=36)	12 (33%)	15 (42%)	7 (19%)	2 (6%)	0 (0%)
PA -no cadaver	6	6	3	2	0
PA-yes cadaver	6	9	4	0	0

Q6 Statement 2 My anatomical knowledge feels fragmented: I cannot see whole body connections.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	2 (3%)	8 (13%)	20 (34%)	24 (40%)	6 (10%)
Dental	2 (8%)	2 (8%)	9 (38%)	9 (38%)	2 (8%)
Dental -no undgrad anatomy	2	0	2	2	1
Dental -yes undergrad anatomy	0	2	7	7	1
PA	0 (0%)	6 (17%)	11 (31%)	15 (42%)	4 (11%)
PA -no cadaver	0	3	3	10	1
PA-yes cadaver	0	3	8	5	3

Q6 Statement 3 I am able to picture a muscle or organ as part of a group or system.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	23 (38%)	25 (42%)	8 (13%)	3 (5%)	1 (2%)
Dental	11 (46%)	10 (42%)	3 (13%)	0 (0%)	0 (0%)
Dental -no undgrad anatomy	2	3	2	0	0
Dental -yes undergrad anatomy	9	7	1	0	0
PA	12 (33%)	15 (42%)	5 (14%)	3 (8%)	1 (3%)
PA -no cadaver	4	7	3	3	0
PA-yes cadaver	8	8	2	0	1

Q6 Statement 4 I perceive different tissue depths accurately.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	16 (27%)	17 (28%)	18 (30%)	9 (15%)	0 (0%)
Dental	9 (38%)	5 (21%)	8 (33%)	2 (8%)	0 (0%)
Dental -no undgrad anatomy	3	0	3	1	0
Dental -yes undergrad anatomy	6	5	5	1	0
PA	7 (19%)	12 (33%)	10 (28%)	7 (19%)	0 (0%)
PA -no cadaver	3	6	5	3	0
PA-yes cadaver	4	6	5	4	0

Q6 Statement 5 I can tell tissue textures apart.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	9 (15%)	27 (45%)	17 (28%)	7 (12%)	0 (0%)
Dental	5 (21%)	9 (38%)	7 (29%)	3 (13%)	0 (0%)
Dental -no undgrad anatomy	1	2	4	0	0
Dental -yes undergrad anatomy	4	7	3	3	0
PA	4 (11%)	18 (50%)	10 (28%)	4 (11%)	0 (0%)
PA -no cadaver	0	8	7	2	0
PA-yes cadaver	4	10	3	2	0

Clinical Anatomy Online Learning Survey Question 7

Q7 Statement 1
I wanted to dissect a cadaver.

Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total (n=59)	32 (54%)	15 (25%)	9 (15%)	1 (2%)	2 (3%)
Dental (n=24)	11 (46%)	7 (29%)	4 (17%)	0 (0%)	2 (8%)
Dental -no undgrad anatomy	5	1	0	0	1
Dental -yes undergrad anatomy	6	6	4	0	1
PA (n=35)	21 (60%)	8 (23%)	5 (14%)	1 (3%)	0 (0%)
PA -no cadaver	11	3	3	0	0
PA-yes cadaver	10	5	2	1	0

Q7 Statement 2
I feel behind on surgery skills because I could not dissect.

Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total (n=59)	18 (31%)	8 (14%)	13 (22%)	12 (20%)	8 (13%)
Dental (n=24)	3 (13%)	5 (21%)	8 (33%)	3 (13%)	5 (21%)
Dental -no undgrad anatomy	0	2	3	1	1
Dental -yes undergrad anatomy	3	3	5	2	4
PA (n=35)	15 (43%)	3 (5%)	9 (26%)	5 (14%)	3 (5%)
PA -no cadaver	9	2	4	1	1
PA-yes cadaver	6	1	5	4	2

Q7 Statement 3 Studying from physical models would have contributed to my anatomical knowledge.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total (n=58)	39 (67%)	11 (19%)	7 (12%)	1 (2%)	0 (0%)
Dental (n=24)	16 (67%)	3 (13%)	4 (17%)	1 (4%)	0 (0%)
Dental -no undgrad anatomy	5	2	0	0	0
Dental -yes undergrad anatomy	11	1	4	1	0
PA (n=34)	23 (68%)	8 (24%)	3 (9%)	0 (0%)	0 (0%)
PA -no cadaver	12	2	2	0	0
PA-yes cadaver	11	6	1	0	0

Q7 Statement 4 Studying from a three-dimensional online atlas is just as good as studying from physical models.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total (n=58)	4 (7%)	4 (7%)	16 (28%)	24 (41%)	10 (17%)
Dental (n=24)	3 (13%)	2 (8%)	5 (21%)	9 (37%)	5 (21%)
Dental -no undgrad anatomy	0	0	1	6	0
Dental -yes undergrad anatomy	3	2	4	3	5
PA (n=34)	1 (3%)	2 (6%)	11 (32%)	15 (44%)	5 (15%)
PA -no cadaver	0	1	7	6	2
PA-yes cadaver	1	1	4	9	3

Clinical Anatomy Online Learning Survey Question 8 & 9

Q8 I bought my own model(s) for this course.		
Program	Yes	No
Total (n=60)	15 (25%)	45 (75%)
Dental (n=24)	6 (25%)	18 (75%)
Dental -no undgrad anatomy	1 (14%)	6 (86%)
Dental -yes undergrad anatomy	5 (29%)	12 (71%)
PA (n=36)	9 (25%)	27 (75%)
PA -no cadaver	3 (18%)	14 (82%)
PA-yes cadaver	6 (32%)	13 (68%)

Q9 Models should be provided by the university for online laboratory courses.		
Program	Yes	No
Total	47 (78%)	13 (22%)
Dental	19 (79%)	5 (21%)
Dental -no undgrad anatomy	6	1
Dental -yes undergrad anatomy	13	4
PA	28 (78%)	8 (22%)
PA -no cadaver	14	3
PA-yes cadaver	14	5

Clinical Anatomy Online Learning Survey Question 10

Q10 Statement 1

Undergraduate cadaveric anatomy contributed to my three-dimensional understanding of a human body in this course.

Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total (n=60)	19 (32%)	10 (17%)	9 (15%)	2 (3%)	20 (33%)
Dental (n=24)	5 (21%)	4 (17%)	3 (13%)	1 (4%)	11 (46%)
Dental -no undgrad anatomy	1	0	1	0	5
Dental -yes undergrad anatomy	4	4	2	1	6
PA (n=36)	14 (39%)	6 (17%)	6 (17%)	1 (3%)	9 (25%)
PA -no cadaver	2	1	4	1	9
PA-yes cadaver	12	5	2	0	0

Q10 Statement 2

Activities that integrate lab and lecture knowledge would have contributed to my learning.

Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	21 (35%)	22 (37%)	13 (22%)	4 (7%)	0 (0%)
Dental	8 (34%)	6 (25%)	8 (34%)	2 (8%)	0 (0%)
Dental -no undgrad anatomy	1	1	5	0	0
Dental -yes undergrad anatomy	7	5	3	2	0
PA	13 (36%)	16 (44%)	5 (14%)	2 (6%)	0 (0%)
PA -no cadaver	7	7	1	2	0
PA-yes cadaver	6	9	4	0	0

Q10 Statement 3 Regardless of my grade, I'm not sure how well I understand anatomy.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	2 (3%)	5 (8%)	11 (18%)	32 (53%)	5 (8%)
Dental	2 (8%)	2 (8%)	5 (21%)	10 (42%)	5 (21%)
Dental -no undgrad anatomy	0	1	2	3	1
Dental -yes undergrad anatomy	2	1	1	7	4
PA	0 (0%)	3 (8%)	6 (17%)	22 (61%)	5 (14%)
PA -no cadaver	0	2	4	11	1
PA-yes cadaver	0	1	2	11	4

Q10 Statement 4 I would like cadaveric review lab time in future classes.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	16 (27%)	22 (37%)	12 (20%)	9 (15%)	1 (2%)
Dental	4 (17%)	11 (46%)	5 (21%)	3 (13%)	1 (4%)
Dental -no undgrad anatomy	1	3	2	0	1
Dental -yes undergrad anatomy	3	8	3	3	0
PA	12 (33%)	11 (31%)	7 (19%)	6 (17%)	0 (0%)
PA -no cadaver	5	5	5	2	0
PA-yes cadaver	7	6	2	4	0

Q10 Statement 5 Reviewing relevant anatomy on a cadaver in future classes would help me visualize anatomical relationships for the whole body.					
Program	Very true for me	fairly true for me	somewhat true for me	not very true for me	not at all true for me
Total	23 (38%)	22 (37%)	14 (23%)	0 (0%)	1 (2%)
Dental	9 (37%)	11 (46%)	3 (13%)	0 (0%)	1 (4%)
Dental -no undgrad anatomy	1	4	1	0	1
Dental - yes undergrad anatomy	8	7	2	0	0
PA	14 (39%)	11 (31%)	11 (31%)	0 (0%)	0 (0%)
PA -no cadaver	5	6	6	0	0
PA-yes cadaver	9	5	5	0	0