Evaluating the Influences of Dissection- and Prosection-based Laboratory Environments and the Use of a Computer-assisted Learning Resource on Students’ Learning Outcomes in Human Anatomy

by

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A Thesis
presented to
The University of Guelph

In partial fulfilment of requirements
for the degree of
Doctor of Philosophy
in
Human Health and Nutritional Sciences

Guelph, Ontario, Canada

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EVALUATING THE INFLUENCES OF DISSECTION- AND PROSECTION-BASED LABORATORY ENVIRONMENTS AND THE USE OF A COMPUTER-ASSISTED LEARNING RESOURCE ON STUDENTS’ LEARNING OUTCOMES IN HUMAN ANATOMY

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Human anatomy is traditionally taught through didactic lectures and interactive dissection-based laboratory activities. This dissection-based format, however, is often limited by factors such as insufficient time, money, personnel, and resources. These limitations have led to the development and widespread use of several alternate teaching approaches in higher education. Two of the most popular alternative approaches to human anatomy education are prosection-based laboratories and the use of computer-assisted learning resources. However, very limited research exists surrounding how these different teaching approaches influence the students’ learning process and long-term outcomes of their learning. Accordingly, through three separate research studies, this work investigated the influences of dissection- and prosection-based laboratories, as well as the use of a computer-assisted learning resource, on students’ subjective course experiences, approaches to learning, academic performance, and long-term anatomical knowledge retention. All three studies used students’ approaches to learning as measures of educational quality, acknowledging the use of deep approaches as representative of meaningful learning. The findings from the first study indicated that an ‘enhanced’ prosection-based design may be a productive approach to teaching anatomy;
however, participation in dissection better encouraged deep approaches to learning and may have promoted skill development. A novel curriculum-targeted computer-assisted learning resource was then created, introduced into the course as a supplemental resource, and evaluated for its impact on learning in the second study. The results indicated that students who reported high satisfaction with the resource used deeper learning approaches in anatomy. The third study examined the influence of the learning environment and use of the resource on long-term knowledge retention. No significant difference in knowledge recall ability was detected between dissection and prosection students; however, use of the computer-assisted learning resource was positively associated with performance on high-order knowledge recall tasks. Taken together, these results support the use of dissection-based laboratories and supplemental computer-assisted learning resources for teaching and learning in human anatomy. However, the prosection-based approach may offer an acceptable option for institutions faced with restrictive limitations. Furthermore, the work in this thesis advocates for the evaluation of educational interventions using multiple different measures of students’ academic success to ensure high-quality outcomes are achieved.
DEDICATION

This thesis is dedicated to my family who have been my strongest pillars of support throughout my journey through higher education, especially my partner, Kate. Further dedications and sincerest thanks are due to the body donors whose selfless gift facilitates the education of thousands of future healthcare professionals each year.
ACKNOWLEDGEMENTS

The author would like to acknowledge several individuals who aided in the planning and execution of the research conducted for this thesis, especially Dr. Gary Umphrey, William Albabish, James Turgeon, Alec Stubbs, and Shoshana Buckhalter whose contributions had direct and immediate impacts on this work. Special thanks are due to Dr. Michael Wiley and Dr. Albert Agro, who made their valuable time available to provide sage guidance, and Dr. Genevieve Newton who was an organizational powerhouse behind this work. Considerable gratitude is due to Dr. Lorraine Jadeski whose vision, expertise, mentorship, and guidance made this degree possible. This work is hers as much as it is mine. Finally, thank you to the Advanced Study in Human Anatomy Class of 2015 who invested their time in various pilot projects, the graduate students and staff members of the human anatomy laboratory for their friendship and support, and the third-year students who volunteered their time and energy to participate in these studies in pursuit of developing a more impactful human anatomy education for future students.
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<td>3-D</td>
<td>three-dimensional</td>
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<tr>
<td>3-P</td>
<td>Presage-Process-Product</td>
</tr>
<tr>
<td>ANCOVA</td>
<td>analysis of covariance</td>
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<tr>
<td>ANOVA</td>
<td>analysis of variance</td>
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<tr>
<td>BAT</td>
<td>Blooming Anatomy Tool</td>
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<td>BIOM</td>
<td>Biomedical Sciences</td>
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<td>BIOS</td>
<td>Biological Sciences</td>
</tr>
<tr>
<td>BLR</td>
<td>binomial logistic regression</td>
</tr>
<tr>
<td>BT</td>
<td>Bloom’s Taxonomy of Educational Objectives</td>
</tr>
<tr>
<td>C</td>
<td>cervical</td>
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<tr>
<td>CAL</td>
<td>computer-assisted learning</td>
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<td>CALRS</td>
<td>Computer-assisted Learning Resource Satisfaction</td>
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<tr>
<td>cDA</td>
<td>contextual deep approach</td>
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<tr>
<td>CE</td>
<td>course experience</td>
</tr>
<tr>
<td>CEQ</td>
<td>Course Experience Questionnaire</td>
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<tr>
<td>CGA</td>
<td>cumulative grade average</td>
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<td>CLT</td>
<td>Cognitive Load Theory</td>
</tr>
<tr>
<td>cSA</td>
<td>contextual surface approach</td>
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<tr>
<td>CT</td>
<td>cœliac trunk</td>
</tr>
<tr>
<td>CTML</td>
<td>Cognitive Theory of Multimedia Learning</td>
</tr>
<tr>
<td>DA</td>
<td>deep approach</td>
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<tr>
<td>DI</td>
<td>dissection-based</td>
</tr>
<tr>
<td>DOF</td>
<td>depth of field</td>
</tr>
<tr>
<td>DSLR</td>
<td>digital single-lens reflex</td>
</tr>
<tr>
<td>FS</td>
<td>focus-stacking</td>
</tr>
<tr>
<td>HK</td>
<td>Human Kinetics</td>
</tr>
<tr>
<td>IMA</td>
<td>inferior mesenteric artery</td>
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<tr>
<td>KRT</td>
<td>knowledge retention test</td>
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<tr>
<td>LOA</td>
<td>laboratory oral assessment</td>
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<td>LT</td>
<td>laboratory test</td>
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<tr>
<td>M</td>
<td>mean</td>
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<td>MLR</td>
<td>multiple linear regression</td>
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<td>pDA</td>
<td>preferred deep approach</td>
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<td>SAL</td>
<td>student approach to learning</td>
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<td>SD</td>
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<td>standard error mean</td>
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<td>SMA</td>
<td>superior mesenteric artery</td>
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<td>SOLO</td>
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<tr>
<td>T</td>
<td>thoracic</td>
</tr>
<tr>
<td>TA</td>
<td>teaching assistant</td>
</tr>
<tr>
<td>UG</td>
<td>University of Guelph</td>
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<td>WT</td>
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1 Literature Review

1.1 Introduction

Human anatomy is the scientific study of the structure and function of the systems, organs, and tissues that comprise the human body. In contrast to fields such as physiology and biochemistry, which deal largely with microscopic and chemical processes, gross human anatomy focuses on the composition, position, and organization of macroscopic structures within the body. From athletic training to specialized surgery and many occupations in between, a strong knowledge of this basic subject is essential to the success of several health professions. Despite its fundamental importance to health-related fields, curricular hours devoted to the study of human anatomy have suffered a decline (Drake et al., 2002; Drake et al., 2009; Craig et al., 2010). This is thought to be largely a result of imbalances in student to demonstrator ratios, the reassignment of curricular time to other disciplines, and the significant costs associated with running a laboratory-based course (Miller and Neal, 1994; McLachlan et al., 2004; Turney, 2007; Drake et al., 2009; Drake et al., 2014). Awareness of this trend has led researchers to investigate the very necessity of teaching human anatomy in medical curricula (Bergman et al., 2008; Böckers et al., 2010; Sugand et al., 2010; Sheikh et al., 2015). Conversely, multiple studies have concluded that the anatomical knowledge of recently graduated doctors was inferior to that of previous cohorts and was even considered by some to be inadequate and concerning (Cottam, 1999; Waterston and Stewart, 2005; Dickson et al., 2009; Roche et al., 2009; Ahmed et al., 2010; Roche et al., 2011). Although the decline of time attributed to human anatomy education appears to be
slowing (Drake et al., 2014), these findings outline a troublesome trend that could have deep implications for patient safety (Goodwin, 2000; Ellis, 2002; Older, 2004; Turney, 2007; Ahmed et al., 2010; Singh et al., 2015).

To accommodate the demand for anatomical fluency in some of society’s most important health-related occupations, the methods by which anatomy is taught in higher-education is in a constant state of evolution. Accordingly, many instructors have turned to alternative approaches that aim to combat the decline of human anatomy education by reducing the cost and time investments of existing anatomy programs. In most cases, these changes involve a transition from laborious full-body dissection-based (DI) laboratories toward less immersive alternatives (McLachlan et al., 2004). Two popular substitutions for the DI laboratory are the use of previously dissected specimens in prosection-based (PRO) laboratories and supplementation with computer-assisted learning (CAL) resources (Topp, 2004; Elizondo-Omaña et al., 2005; Losco et al., 2017; Wilson et al., 2018). Given the growing reliance on these alternative designs, it is of great interest to thoroughly investigate the pedagogical outcomes that may result from their implementation to ensure that the quality of human anatomy education is not compromised.

This chapter will first review the current landscape of human anatomy learning in higher-education with a focus on DI and PRO laboratory environments, as well as the use of CAL in human anatomy instruction. The measurement of learning for research purposes will then be explored with respect to popular epistemologies and commonly investigated learning outcomes. Specifically, the philosophies of behaviourism,
cognitivism, and constructivism and their influences on how researchers measure the learning process and outcomes that represent academic success such as performance, skill development, and knowledge retention will be discussed.

1.2 Teaching Human Anatomy

1.2.1 Traditional Dissection-based Human Anatomy Education

Dissection has been at the heart of human anatomy teaching for hundreds of years (Persaud, 1984). The process is so deeply integrated into the field that it is cemented in the word, anatomy (Greek: ana-, “up” and tomia, “cutting”), itself. For many years, the predominant method of human anatomy instruction came in the form of didactic lectures and dissection-podium demonstrations. These practices typically transpired in instructor-centric anatomical theatres and the dissections were performed by experienced professors. Over subsequent centuries, however, ‘traditional’ anatomical instruction has grown increasingly student-centric (Terrell, 2006). Today, a traditional DI human anatomy course can be loosely defined as one that teaches fundamental anatomical content in lecture sessions which are then complimented by laboratories that include some form of cadaveric dissection performed by the students. During these laboratory sessions, small groups of students selectively remove skin, fat, and connective tissue to eventually reveal the underlying structures of interest and their spatial relationships to one another. Depending on the region, these structures may include muscles, organs, nerves, arteries, or any other component that is relevant to the curriculum. The specific qualities of DI courses vary between institutions. However, the DI approach in general has long been considered the gold-standard for human anatomy education, as it is thought to promote
the development of both practical and transferrable skills (Ellis, 2001; Aziz et al., 2002; Granger, 2004; Older, 2004; Pawlina and Lachman, 2004; Patel and Moxham, 2008; Korf et al. 2008; Rehkämper, 2016).

The process of dissection contributes to many advantageous ‘hard’ (measurable) outcomes such as knowledge, comprehension, and application of human anatomy. While lectures impart factual knowledge about the body’s structures and relationships, dissection offers the opportunity to directly apply that knowledge, allowing the students to formulate a comprehensive three-dimensional (3-D) view of the human body (Dinsmore et al., 1999; Marks, 2000; Aziz et al., 2002; Granger, 2004; Korf et al., 2008). This visualization helps students to better comprehend how structures relate to one another in space and establishes an understanding of depth and organization (Collins, 2008). In addition to this visual reinforcement, dissection activates a number of other sensory inputs to enrich the students’ learning. For instance, students use the physical act of cutting and separating tissue to achieve a touch-mediated perception of the body, while honing manual skills that are beneficial to certain medical professions (Ellis, 2001; Aziz et al., 2002; Granger, 2004; Older, 2004; Inwood and Ahmad, 2005). This hands-on approach can lead to meaningful learning, which is linked with increased academic success and stronger knowledge retention (see Section 1.3.2) (Trigwell and Prosser, 1991; Michael, 2006; Ward and Walker, 2008). The process of dissection also occurs in a novel environment for the students, subjecting them to typically new olfactory, auditory, and visual experiences. This combination of multiple sensory inputs creates an intricate
experiential learning context which is thought to be an important contributor to student learning (Kolb, 1984; Kauffman and Mann, 2010).

Further benefits to hard skill development become evident when the social dynamic of the DI laboratory is considered. Throughout the duration of a DI course, not only do the students learn from the cadaver they are assigned to, but also from the other cadavers present in the laboratory. Since the students are free to visit the work stations of their peers, they have the opportunity to observe the many anatomical variations that may be found (Tubbs et al., 2016). This exposure to unpredictable anatomy confronts the entire class with an awareness of anatomical variability that may help them avoid misdiagnosis and malpractice once they become active professionals (Willan and Humpherson, 1999; Tubbs et al., 2016). All the while, by using the terminologica anatomica in conversations with their peers, the students are becoming familiar with the “language of medicine” through habituation, not through memorization (Granger, 2004). Overall, learning these skills and principles in an experiential setting, rather than through theoretical study, increases the likelihood that they will become automatic when the students interact with their future patients (Kauffman and Mann, 2010).

Most students who complete an anatomy course aim to eventually serve as healthcare professionals in some capacity. These types of occupations often involve direct interaction with patients. For this reason, the development of interpersonal skills is an increasingly popular goal for health science education (Dyer and Thorndike, 2000; Gregory and Cole, 2002; Lempp, 2005). In addition to refining basic practical skills, following a DI approach to human anatomy education has also been credited with
promoting many positive ‘soft’ (transferable) skills. Learning in a DI environment is believed to encourage personal development in aspiring health care professionals by inspiring respect, professionalism, a humanistic approach to patient care, and the acceptance of death (Aziz et al., 2002; Rizzolo, 2002; Granger, 2004; Pawlina and Lachman, 2004; Escobar-Poni and Poni, 2006; Lachman and Pawlina, 2006; Chaudhuri, 2007; Korf et al., 2008; Canby and Bush, 2010; Rehkämper, 2016). Furthermore, the small-group setting of most DI laboratories cultivates teamwork and communication skills as students work through the challenging emotional novelty and academic demands of the cadaver laboratory (Moore, 1998; Newell, 1995; Fitzpatrick et al., 2001; Aziz et al., 2002; Granger, 2004; Rehkämper, 2016). These skills are undoubtedly important, not only in professional health-related fields, but also in each student’s own personal development.

As the extrinsic financial and resource-related pressures of a rapidly changing academic climate in medical education continue, an increasing number of institutions are being forced to consider alternative approaches to DI human anatomy instruction. Popular perception of anatomy as a subject that is overly factual and easily learned through memorization has led to widespread reductions in its teaching and integration with other basic scientific disciplines (Aziz et al., 2002; Drake et al., 2002; Turney, 2007; Drake et al., 2009; Sugand et al., 2010; Kerby et al., 2011; Drake et al., 2014). Furthermore, accounting for the staff and resources required, the cost of running a DI laboratory is notoriously high (McLachlan et al., 2004; McLachlan and Patten, 2006; Korf et al., 2008). To combat these restrictions in time and financial feasibility, many institutions are
exploring alternative methods that reduce or entirely remove elements of dissection and cadaver use (Collins et al., 1994; McLachlan et al., 2004). Some of these alternatives are believed to offer equal opportunities for knowledge dissemination and skill development as are possible using a DI approach (Nnodim, 1990; Nnodim et al., 1996; McLachlan et al., 2004; McLachlan, 2004; Topp, 2004). However, conclusive and reliable evidence to support either side of this debate is scarce (Wilson et al., 2018).

1.2.2 Prosection-based Human Anatomy Education

Arguably, the most popular instructional design implemented to replace traditional DI human anatomy education is the PRO laboratory. While both DI and PRO laboratories use cadaveric specimens, they require different levels of physical involvement by the students. In a DI laboratory, the students are required to complete the laborious process of carefully removing skin, fat, and connective tissue to reveal the desired structures. On the other hand, PRO laboratories allow the students to use previously dissected specimens to observe the structures of focus without the distracting or “messy” back-drop of undesirable tissues. These prosections are usually prepared by the teaching staff or laboratory technicians, and thus do not require any investment of physical labour by the students, drastically reducing the amount of time they must commit to the laboratory. Moreover, in comparison to DI, which requires new cadavers each academic cycle, prosected specimens that have been properly preserved and maintained can be used for teaching many groups of students for several years at a relatively low cost. The obvious time and cost benefits of PRO learning have prompted many articles to debate the necessity of DI and evaluate the prospect of PRO anatomy as an educationally equivalent
alternative (Nnodim, 1990; Nnodim et al., 1996; Yeager, 1996; Dinsmore et al., 1999; Johnson, 2002; Older, 2004; Granger, 2004; Pawlina and Lachman, 2004; Topp, 2004; McLachlan, 2004; McLachlan et al., 2004; Elizondo-Omaña et al., 2005; Rizzolo and Stewart, 2006; Azer and Eizenberg, 2007; Turney, 2007; Winklmann, 2007; Smith et al., 2014; Rehkämper, 2016; Wilson et al., 2018). Those who state a preference for the PRO approach argue that it alleviates a number of the extrinsic pressures that curtail the DI approach, while maintaining crucial learning outcomes achieved through the act of dissection (Nnodim, 1990; Nnodim et al. 1996; Johnson, 2002; Topp, 2004).

Although they are often the driving forces behind changes in curricular design, extrinsic pressures such as time and cost should not be the primary focus when determining the learning activities to be used within a course – maximizing the knowledge and skills that the students gain through participation in the course activities should take priority. However, sometimes there exists an overlap between these two domains. For instance, many students prefer PRO laboratories because they consider them to be more time-efficient, since the use of prosections allows the students to bypass the dissection process and quickly advance to learning the material (Dinsmore et al., 1999). Given the influence that a student’s perception of a course can have on their approach to learning and their subsequent performance (see Section 1.3.2), the efficiency of PRO laboratories may ultimately lead to improved student learning (Entwistle and Tait, 1990; Trigwell and Prosser, 1991; Lizzio et al., 2002). However, regardless of time and cost, the use of prosections must sufficiently match DI laboratories in their ability to facilitate the development of both hard and soft skills to be considered as a valid alternative approach.
An important consideration for a shift toward PRO environments is their capacity to reinforce factual anatomical information obtained in lecture. For this outcome, the PRO laboratory is generally thought to meet, and even exceed, the standards set by the DI laboratory (Topp, 2004; Wilson et al., 2018). Namely, since the preparation of a prosected specimen involves the professional removal of unwanted tissue to highlight an area of interest, the specimen effectively becomes a simplified version of that region, requiring less cognitive load to process (Sweller, 1988; Mayer and Moreno, 2003). In this way, series of prosections can allow the students to start simple and build toward more detailed specimens with more complex anatomy. This simplification may facilitate better 3-D understanding of the human body than can be obtained by navigating through an intricate dissection (Marks, 2000; Miller, 2000; Topp, 2004). Furthermore, although some argue that the hands-on component in PRO does not compete with that of DI, both environments often involve some degree of physicality and the integration of multiple sensory inputs including vision, touch, and smell (Granger, 2004; Topp, 2004; Qamar and Osama, 2014). Many PRO laboratories require the students to manipulate the specimens in order to visualize important anatomical structures. Since they both use cadaveric materials, DI and PRO laboratories occur in a similar experiential learning environment that confronts the students with comparable sensory cues. These multisensory hands-on activities are known to be beneficial to the promotion of meaningful learning (Kolb, 1984; Trigwell and Prosser, 1991; Michael, 2006; Ward and Walker, 2008; Kauffman and Mann, 2010). An opportunity that is inherently lost when a program moves away from DI instruction is the potential for students to acquire practical manual skills. In DI, these skills are obtained
incidentally by using tools to physically navigate the body; however, PRO does not demand such practices. While these skills may be helpful for a future surgeon, they are not, however, necessary to learn the basic anatomy of the human body. Moreover, the use of embalmed cadavers for dissection has been criticized for providing students with a manual experience that does not accurately mimic the fresh human tissues that they will encounter in future medical and health practices, thereby misinforming their touch-mediated perception of the body and manual skills (McLachlan et al., 2004; Topp, 2004). For these reasons, some speculate that the integration of manual skills, such as surface palpation of live patients, alongside PRO teaching may be more valuable to most students’ professional development than the fine motor skills related to dissection (Ellis, 2001; McLachlan et al., 2004; Topp, 2004).

The DI and PRO laboratories are nearly indistinguishable when comparing the influences imposed by the social aspect of each laboratory environment. First, in a PRO laboratory, students are often equally as free to move around the laboratory as those in a DI laboratory. In fact, PRO students may have more available time to visit different specimens and observe more anatomical variations than would be possible if they were responsible for dissecting a single cadaver (Topp, 2004). Similarly, the *terminologica anatomica* is not exclusive to DI – as the students move from specimen to specimen, they will use this “language of medicine” to identify the structures they find and discuss these findings with their peers. Thus, the PRO approach can support the development of teamwork and communication skills while concomitantly fostering awareness of anatomical variations (Topp, 2004). In addition, although students do not physically cut
the tissue, they still face the emotional challenge of interacting with donated human bodies. Given this parallel in psychosocial context with the DI laboratory environment, PRO learning is likely a close match to DI in its ability to foster the development of soft skills such as respect, professionalism, a humanistic approach to patient care, and gaining an acceptance of death. To confound the debate, many of the arguments both for and against DI or PRO learning and soft skill development rely largely on student and instructor perspectives, but lack reliable objective quantification (Colliver and McGahie, 2008).

Since most institutions provide only one type of laboratory environment, direct comparisons between DI and PRO approaches are rare. Because of this, findings of studies performed at different institutions tend to yield tenuous conclusions (Johnson, 2002). For example, Smith and Mathias (2007) found that the majority of students enrolled in a PRO laboratory environment assumed a deeper approach to learning, which is correlated with academic success and meaningful learning (see Section 1.3.2) (van Rossum and Schenk, 1984; Trigwell and Prosser, 1991; Newstead, 1992; Gibbs, 1994; Norton and Dickens, 1995; Zimitat and McAlpine, 2003; Pandey and Zimitat, 2007). In contrast, in a study by Ward (2011), the majority of students in a DI course showed the same tendency toward high-quality learning. Since these studies used different populations, procedures, and course designs, one cannot make fully accurate comparisons between the two laboratory approaches and their relative capacities to promote deep engagement; however, the findings suggest that both approaches are conducive to high-quality learning. A similar trend is seen in research investigating the
retention of anatomical knowledge. Taking a deeper approach to learning anatomy has been linked to improved knowledge recall, and both PRO and DI approaches have been shown to elicit high rates of recall and recognition of anatomical knowledge in different populations (Blunt and Blizard, 1975; Ward and Walker, 2008; Doomernik et al., 2017). Although one study did directly compare students enrolled in DI and PRO laboratories, it found no significant differences in knowledge recall between them (Sinclair, 1965). While these studies paint a more quantitative picture of learning in the anatomy laboratory, more direct comparisons between DI and PRO approaches are required to ensure they provide equivalent learning opportunities. However, as the educational landscape continues to evolve, ‘pure’ DI and PRO laboratories are becoming increasingly rare. Many institutions have integrated technology into their existing programs to circumvent temporal and financial pressures, limiting the opportunity for unadulterated comparisons. These CAL resources have their own influences on the learning environment that should also be investigated for their contributions to student learning.

1.2.3 Computer-assisted Learning in Human Anatomy Education

CAL is a hypernym for the use of computer-based multimedia tools as educational resources. These tools can range from simple digital picture atlases to instructional videos, interactive 3-D digital models, and virtual reality (Johnson et al., 2012; Losco et al., 2017). With ongoing and rapid advancements in digital media technology, CAL has played an increasingly important role in modern education (Losco et al., 2017). Despite its status as one of the oldest sciences in existence, human anatomy has evolved alongside these technologies in an effort to maintain modern relevance in an ever-
changing academic landscape. As a subject that relies heavily on visual reinforcement to learn, human anatomy has benefitted greatly from improvements in imaging technology and the growing convenience of computing devices. CAL tools have already been integrated into many curricula to supplement, and even replace, the cadaveric components of human anatomy courses in response to mounting extrinsic pressures (Granger and Calleson, 2007; Adamczyk et al., 2009; McNulty et al., 2009; Johnson et al., 2012; Wright, 2012; Barbeau et al., 2013; Attardi and Rogers, 2015; Losco et al., 2017). The increased reliance on CAL use has been further encouraged by the arrival of the millennial generation of students (dubbed ‘digital natives’), who are comfortable with, and even prefer, the use of technology in education (Prensky, 2001; Lancaster and Stillman, 2003; Wessels et al., 2015; Pettit et al., 2017). However, the appropriate characteristics and circumstances for CAL implementation in human anatomy are still debated among educators in the academic community (Granger and Calleson, 2007; Tam et al., 2009; McNulty et al., 2009; Mahmud et al., 2011; Topping, 2014; Losco et al., 2017; Vaccarezza, 2018).

CAL offers a flexible adjunct to instructional designs that can be used in various learning contexts. In human anatomy education, CAL resources have been disseminated in environments such as lecture, laboratory, and via online learning platforms (van Sint Jan et al., 2003; McNulty et al., 2009; Venkatiah, 2010; Wright, 2012; Attardi and Rogers, 2015; Losco et al., 2017). In each of these forums, CAL tools provide a variety of pedagogical opportunities; however, since they are often developed and implemented differently at each institution, it is difficult to determine the ideal circumstances for their
use (Losco et al., 2017). CAL tools are believed to successfully support existing instructional designs by demonstrating structures and concepts that are difficult to conceptualize using textbooks or cadavers (Tam et al., 2009). These qualities suggest that CAL tools may have the potential to be used effectively as in-laboratory resources to aid students in their development of a 3-D understanding of the body. Accordingly, some studies have found that CAL in the form of 3-D digital anatomy models significantly improved student learning compared to traditional approaches (Qayumi et al., 2004; Nicholson et al., 2006; Glittenberg and Binder, 2006; Brewer et al., 2012; Losco et al., 2017). Students have also reported that they enjoy the use of CAL aids implemented alongside traditional laboratory activities, which may encourage them to take a deeper approach to learning (see Section 1.3.2) (Entwistle and Tait, 1990; Trigwell and Prosser, 1991; Lizzio et al., 2002; McNulty et al., 2009; Venkatiah, 2010; Weber et al., 2012). Furthermore, a study by Reeves and colleagues (2004) concluded that the introduction of a computer-based dissection manual encouraged self-directed learning in the laboratory. Self-directed learning has been shown to be associated with higher student engagement and increased use of deep learning approaches, ultimately improving comprehension of human anatomy (Findlater et al., 2012). This echoes findings from pedagogical research outside of human anatomy education that indicates student proclivity for deeper learning when they are actively engaged (Cake, 2006; Gillingwater, 2008). Finally, as human anatomy is an especially visual field, videos can serve as helpful teaching tools. CAL resources in the form of dissection videos have been shown to improve student learning outcomes by multiple studies (Sultana et al., 2001; Pereira et
al., 2004; DiLullo et al., 2006; Saxena et al., 2008; Topping, 2014; Losco et al., 2017). Other CAL tools to support DI have also yielded beneficial results, namely by promoting efficient use of dissection time by students (Reeves et al., 2004). In an era where curricular time devoted to human anatomy education is remarkably low (Drake et al., 2009; Drake et al., 2014), improved student efficiency in the DI laboratory through supplemental CAL resources may allow programs who face this challenge to continue the use of cadaver-based learning environments with minimal increases in expenditure (Reeves et al., 2004). Various designs for CAL tools continue to be evaluated to identify features that promote these, and other, positive learning outcomes.

While many ‘modernists’ advocate for increased CAL use in human anatomy education, the ‘traditionalists’ tend to be less enthusiastic (Turney, 2007). For the most part, the sentiment shared by traditionalists is not that all CAL use is detrimental to learning, but that using CAL in place of cadaver-based approaches may support some areas of student learning at the cost of many other beneficial learning opportunities that are typically obtained through DI or PRO teaching (see Sections 1.2.1 and 1.2.2). Some findings, however, suggest that CAL offers few benefits aside from the financial. For instance, when students who used CAL to learn anatomy were compared to those who used paper-based resources, no significant differences were seen in performance or knowledge retention (Khalil et al., 2005; Corton et al., 2006). Research evaluating video-based CAL resources has made similar observations – some findings indicate that the use of dissection videos offers no benefit, and sometimes reduces student performance in human anatomy (Granger and Calleson, 2007; McNulty et al., 2009; Mahmud et al.,
While these findings cast a shadow on the more extreme modernist argument for abandoning cadaver-based approaches entirely, others propose a more moderate interpretation that is better fit to appeal to the attitudes of most traditionalists. For instance, in a 2009 review, Tam and colleagues concluded that the available evidence supported the use of 3-D digital models as helpful adjuncts to human anatomy education, but it was insufficient to advocate for their ability to totally replace traditional cadaver-based methods (Tam et al., 2009). In addition, many of the studies that found benefits to CAL did so in a curriculum that involved some form of cadaver-based education (Reeves, 2004; DiLullo et al., 2006; Saxena et al., 2008; Venkatiah, 2010; Weber et al., 2012; Topping, 2014; Losco et al., 2017).

Although the current evidence does not support CAL as an outright replacement for traditional educational approaches in human anatomy, many findings support its use as a supplemental adjunct in blended learning environments (Losco et al., 2017). Overall, continued investigation into the educational strengths and weaknesses of CAL is required to establish its optimal role in human anatomy education.

1.3 Measuring Student Learning

Learning is a fundamentally difficult outcome to measure. Accordingly, how researchers attempt to measure learning depends largely on their individual epistemology and constraints on the design of the experiment. While this has led to extensive use of student performance as evidence of learning, there is warranted skepticism about the reliability of academic grades to represent success in higher education (Young, 1990; Arum and Roksa, 2011; York et al., 2015). Most educators consider a variety of learning
outcomes, some of which that are less tangible and not necessarily reflected in academic grades, to be meaningful markers of a student’s success (York et al., 2015). Namely, skill-based outcomes, or outcomes that otherwise represent a transformation in the way that the student views the world, are often prioritized (Kuh et al., 2006; York et al., 2015). Ultimately, the question of what constitutes ‘meaningful’ learning is fundamental in determining how learning is measured in education and research.

The following section will attempt to unpack three of the most popular educational philosophies to discern a plausible approach to measuring learning in higher education. The elements of behaviourism, cognitivism, and constructivism that underlie how researchers think about learning and how it is evidenced in the students will be discussed. Particular attention will be given to how students approach their studies and how that can influence various learning outcomes including performance, skill development, and knowledge retention.

1.3.1 Theories of Learning

Throughout the last century, the way that learning is viewed has evolved over time. Various popular epistemologies have emerged that debate theories about how learning occurs, how it is measured, and even where knowledge and reality truly exist – in the mind or external to the learner. Despite their disagreement on a universal definition of learning, these theories share various common elements that have been used to inform several frameworks for instructional design and educational research. By exploring how learning is understood and described by behaviourist, cognitivist, and constructivist
epistemologies, one can establish a more plausible and theoretically sound approach to measuring learning for research than simply through academic grades.

1.3.1.1 **Behaviourism**

A popular epistemological psychology that arose in the early 20th century was behaviourism. Behaviourism was an attempt to bring more objective science into psychology research (Moore, 2011). The theory asserts that learning is a product of an individual’s interaction with their environment, which can be augmented to condition a desired behavioural response (Boghossian, 2006). Ultimately, the behavioural response elicited by these interactions is taken as evidence of learning. This process of behavioural conditioning was most famously demonstrated by Pavlov, who linked the unconditioned salivation response to food in dogs to the ringing of a bell; however, humans have also been shown to respond to Pavlovian (classic) conditioning. For example, in the ‘Little Albert’ experiment, Watson and Rayner (1920) exposed an infant to various animals and other stimuli, including a white rat. Initially, the infant showed no emotional response to any of the animals, but through classic conditioning that paired the appearance of a white rat with the sound of a hammer loudly striking a steel bar (startling the child and causing him to burst into tears), he grew to fear the rat, even without the sound of the hammer on steel (Watson and Rayner, 1920). In this experiment, the infant’s fear response demonstrated a change in behaviour that was taken as evidence of learning.

Although classic conditioning is not the predominant method of academic instruction, its underlying behaviourist foundation has maintained a powerful influence on the modern educational system. The initial theories of instructional design emerged
alongside behaviourism, therefore rooting most academic instruction in behaviourist ideology (Ertmer and Newby, 1993). As a result, the primary assumption that academia and education is based upon is the behaviourist perspective of knowledge. Behaviourism observes the basic tenets of ‘objectivism’, in which truth and knowledge are believed to exist external to the individual and, therefore, reality is not influenced by the individual’s mind (Boghossian, 2006). The learner must gradually uncover knowledge through interactions with their environment and then react to those environmental stimuli based upon their past experiences (Boghossian, 2006). Learning is ultimately evaluated through observations of changes in the student’s behaviour (Boghossian, 2006). Instead of using classic conditioning to attain learning goals, however, most current educational designs employ ‘operant’ conditioning. Operant conditioning is an enriched form of classic conditioning that involves the use of positive or negative reinforcement to train a behaviour (Skinner, 1948). To elicit a desired behaviour, appropriate learner behaviours are rewarded, whereas unwanted or incorrect behaviours are punished (Skinner, 1948). Grade-based assessment is a prime example of behaviourism through operant conditioning in the modern classroom. In school, students are introduced to information that they are expected to view as objective truth. They then participate in learning activities and study, or condition themselves, to associate different bits of information together to form knowledge. Finally, they face an assessment of their learning, in which they exhibit their learned behaviours (i.e., writing answers on a test, performing a dissertation, etc.) and receive feedback on the success of their learning. Behaviours deemed ‘correct’ receive positive reinforcement by being awarded grades, while those
that are ‘incorrect’ result in lost grades, or negative reinforcement. In the human anatomy laboratory, this type of conditioning may most directly apply to the development of desirable skills and behaviours for future healthcare professionals such as respect and professionalism (Pawlina and Lachman, 2004; Lachman and Pawlina, 2006). In alignment with the notion of the cadaver as a student’s ‘first patient’, disrespectful and unprofessional behaviour is actively discouraged, conditioning the students to assume a certain demeanor that is expected of them in their future careers (Lachman and Pawlina, 2006). Again, however, by viewing the student’s role in learning as passive and reactive, the behaviourist epistemology denies any role of the mind in learning (Ertmer and Newby, 1993). In fact, behaviourists view thought itself as a behaviour, rather than a process that contributes to learning (Ertmer and Newby, 1993). Furthermore, a learner’s ability to reproduce a desired effect is thought to be achieved through forming habits rather than memories (Schunk, 2012). Accordingly, behaviourist methods of measuring learning do not necessarily distinguish between whether students with lower grades failed to learn and remember the content correctly, or if they had simply failed to demonstrate the specific desired response designated by the instructor.

The behaviourist approach is appealing in educational research because it allows for easily measured learning outcomes and straightforward ranking of student aptitude. Furthermore, behaviourist techniques can be valuable for the promotion of certain characteristics that are desirable in future healthcare professionals. However, the philosophy does not recognize a role of the mind in how students grow to understand material. As a result, complex cognitive processes such as critical thought, problem
solving, and communication are not acknowledged. This omission has pushed many educators toward philosophies that focus on mental processing in teaching and learning, rather than overt behaviour.

1.3.1.2 Cognitivism

Cognitivism gained popularity as a response to behaviourism that focused on the role of a learner’s thoughts in the learning process (Shuell, 1986). While behaviourists view thought as a behaviour, cognitivists assert that a person’s thoughts influence how they behave, and thus cannot be behaviours themselves (Winne, 1985). Specifically, cognitivism focuses on the processes of knowledge acquisition, organization, storage, and retrieval within the student’s mind as central to describing what students know and how they came to know it (Jonassen, 1991). At first, cognitivist teaching approaches do not appear very different from those inherent to behaviourism. For example, both approaches view learning as facilitated by environmental cues that are scaffolded from simple to more complex tasks, and that knowledge is advanced through practice and corrective feedback (Ertmer and Newby, 1993). Furthermore, both epistemologies support the objectivist definition of reality, in which knowledge and reality exist external to the learner, so learning can therefore be measured through academic examinations that evaluate the successful reproduction of those objective truths (Jonassen, 1991). However, because of the acknowledgment of the mind in cognitivism, cognitivist teaching strategies target learning through different mechanisms than behaviourist approaches.

Where behaviourism and cognitivism primarily differ is in their design of the learning environment and presentation of information. Because cognitivists believe that
the learner’s mind can actively shape their knowledge, particular focus is placed on organizing information in a way that facilitates optimal processing and integration of that knowledge with their existing mental structures (Ertmer and Newby, 1993). This could include strategies such as concept mapping, mnemonics, and analogies that make it easier for students to mentally organize new information and relate it to their existing memories (West et al., 1991). Cognitivist teaching approaches are commonplace in human anatomy education. For instance, if one were to take a cognitivist approach to teaching the organization of the visceral and parietal layers of the pleural membranes that surround the lungs, one may construct a representational analogy that the students could use to relate the new information with what they already know, such as a fist punching a balloon. In this example, the fist is used to represent a lung, while the balloon is a continuous layer that represents a pleural sac – the part of the balloon that is in direct contact with the fist represents the visceral layer, while the surface that is not touching the fist represents the parietal layer. Going forward, the student can use their existing understanding of this unrelated phenomenon (a fist punching a balloon) as a mental representation explaining the concept of organ invagination. Once these fundamental relationships are understood, the learner can expand their knowledge to include more complex concepts such as how respiration is driven by actions of the diaphragm and muscles of the thoracic cage via vacuum pressure between these pleural layers and the lungs, rather than by the lungs themselves. Ultimately, this change in the student’s understanding of how respiration works is what cognitivists use to define learning. In other
words, learning is viewed as a change in the schemata through which the learner views the world, independent of their behaviour (Ertmer and Newby, 1993).

While the cognitivist epistemology allows for important research into how the mind works by rejecting the behaviourist idea of the mind as a ‘black box’, this freedom makes learning harder to quantify. If the learner can hold knowledge and understanding in their mind without it being reflected in their behaviour, the entirety of their learning may not be represented by their academic performance. This notion not only casts doubt upon whether academic grades are the most reliable and accurate measures of student aptitude, it also opens the possibility that each learner has a different depth of understanding of the subject matter. Accordingly, various frameworks have emerged that attempt to measure learning by focusing on the cognitive process, rather than academic performance (see Section 1.3.2), and the mere definition of knowledge has even been called into question.

1.3.1.3 Constructivism

A major learning philosophy that has gained popularity in recent decades is constructivism. Like cognitivism, constructivism acknowledges the mind as the central player in the learning process; however, it fundamentally differs in its theory of knowledge, truth, and what individuals perceive as reality (Ertmer and Newby, 1993). While cognitivism and behaviourism support the objectivist definition of reality in which truth and knowledge exist external to the learner, constructivists believe that individuals create their own meaning of reality based upon their past experiences, previously existing beliefs, knowledge, and understanding of the world (Bichelmeyer and Hsu, 1999). Therefore,
while objectivism-rooted learning theories consider the factors that affect a student’s knowledge (i.e., sensory perception, memory, faith, intuition, imagination, etc.) to be biases that decrease the efficiency of their path towards truth, constructivists view these influences as building-blocks toward the learner’s ultimate understanding (Driscoll, 1994). In this way, learners progressively build and refine an individual knowledge through observation and critical reflection (Bichelmeyer and Hsu, 1999). However, whereas behaviourists employ conditioning techniques for teaching and cognitivists attempt to impart organized mental representations of the material through analogies and memory tricks, constructivism does not include fundamentally associated methodological approaches to teaching (Biggs, 1996). Instead, various suggestions that extend from constructivist principles have been put forth to improve learning quality such as allowing the student to create their own goals for evaluation, designing authentic learning tasks and evaluating knowledge through its application in relevant contexts, allowing for the incorporation of multiple perspectives through social interactions, and providing opportunities for reflection and self-evaluation (Ertmer and Newby, 1993). These guidelines promote a focus on learning quality and allow the student to create a more richly textured understanding of the subject with each time the material is encountered.

Despite the historically pervasive objectivist educational system, some instructional approaches use various elements of constructivist theory to pursue intended outcomes of learning. The Socratic teaching method, for one, uses constructivist concepts of social learning to attain objectivist learning goals (Boghossian, 2006). For instance, a Socratic teacher believes that there is one true and correct answer
(objectivism), but they allow the student to construct their own understanding of that truth through guided discussion and targeted prompts (Boghossian, 2006). Although this approach acknowledges learning as a socially constructive process wherein knowledge is built rather than viewing it as a ‘finding process’ in which knowledge is acquired, it is not entirely constructivist in its fundamental epistemology (Boghossian, 2006). This type of approach is common in DI human anatomy laboratory environments. In the DI laboratory, students are encouraged to learn by discovery as they navigate through the different layers of tissue. When a new structure is uncovered, both the student and the teacher must use their existing knowledge to determine what structure it is based on its size, shape, and location. In this scenario, the presumably more experienced teacher can offer prompting guidance to the student until an agreement on the name of the structure is reached through social construction. This process can continue until a comprehensive understanding of the whole body is reached.

A more ‘macro-level’ approach that uses constructivist theory in instructional design is constructive alignment (Biggs, 1996; Biggs and Tang, 2011). This approach modified Cohen’s (1987) instructional alignment principle by applying constructivist principles to the design of learning objectives, learning activities, and methods of evaluation (Biggs, 1996; Biggs and Tang, 2011). However, rather than setting specific objectives and evaluating them quantitatively, a constructively aligned course would allow for general and malleable learning outcomes that are evaluated by the students, themselves, through a process of reflection (Biggs, 1996; Biggs and Tang, 2011). This is because a constructivist learner is expected to create their own understanding of the truth,
so it is therefore impossible for an instructor or researcher to predict, dictate, or evaluate the ultimate outcome of their learning (Bichelmeyer and Hsu, 1999). This idea presents many challenges when attempting to find evidence of learning to support or refute novel teaching interventions (Biggs, 1996).

Because of the variability in successful learning outcomes associated with constructivist designs (Biggs, 1996), traditional appraisals of learning such as academic performance cannot be used alone. Instead, assessments of the learning environment and the approaches taken by the students when studying the material are often used to provide insight into the degree to which meaningful learning has been achieved (Wang et al., 2013). This concept of meaningful learning is often underrepresented in the field of human anatomy. Many view human anatomy as an information-dense subject that is best learned through memorization of facts (Aziz et al., 2002). However, a constructivist may argue that each individual student possesses their own nuanced and unique understanding of those facts that is a product of their past experiences and the circumstances of their interactions with the material (Ertmer and Newby, 1993). Therefore, when structuring and evaluating learning environments, it is important to consider each student’s approach to learning with equal or greater value as their performance on course assessments.

1.3.2 Student Approach to Learning

Traditional educational designs are well equipped to assess learning quantity though academic assessments that evaluate student knowledge and understanding against a set of predetermined desirable outcomes. This design, however, pays little
respect to the constructivist notion of individually created meaning and the quality of each student’s understanding (Ertmer and Newby, 1993). However, assessing the quality of learning is inherently difficult if each student does in fact possess a unique understanding of the material. For this reason, several frameworks for the evaluation of learning quality have been developed to target the learning process, rather than the learning outcome (Ertmer and Newby, 1993). These approaches operate on the constructivist assumption that meaningful learning is a product of deep engagement with the material in which new information is actively integrated with past knowledge and experiences to advance ultimate understanding (Jonassen, 1991). Therefore, learning quality is dependent upon an interaction between the learning environment and how the student interacts with that environment, which has come to be known as student approach to learning (SAL) (Marton and Säljö, 1976; Biggs, 1987).

SAL is a pedagogical framework created to describe the process through which students interact with their environment to reach their ultimate understanding of the target material (Marton and Säljö, 1976; Biggs, 1987). According to this construct, a major factor that governs the quality of a student’s learning is their motivation to learn the topic and the subsequent strategies (s)he employs to do so (Biggs, 1987; Beghetto, 2004). This motivation is ultimately rooted within each individual student as an outcome of their past experiences and previous understanding of the subject (Biggs, 1987). Accordingly, the SAL framework can be expressed with a step-wise structure known as the ‘presage-process-product’ (3-P) model of learning (Biggs, 1987). The 3-P model views learning (the product) as a direct result of interactions between the student’s background
characteristics and the set learning environment (presage factors), which determines the ways in which (s)he chooses to study the material in that context (the process) (Biggs, 1987). Consistent with this theory, intrinsic presage factors such as the student’s age and sex have since been shown to influence SAL (Groves, 2005; Baeten et al., 2010; Rubin et al., 2016), as have indirect measures of the learning environment, such as their satisfaction with the course and interest in its content (Entwistle and Tait, 1990; Trigwell and Prosser, 1991; Lizzio et al., 2002). Each individual’s SAL is typically ranked on both a deep approach (DA) and surface approach (SA) to learning scale (Marton and Säljö, 1976; Biggs, 1987). Students who implement DAs to learning strive to obtain a meaningful and nuanced understanding of the topic through high-level engagement, whereas SAs generally involve lower-level engagement strategies, such as rote memorization, that result in a superficial understanding of facts (Marton and Säljö, 1976). Since the use of DAs to learning has been repeatedly tied to greater academic success and is generally considered to be representative of meaningful learning, building learning environments that encourage DAs to learning is widely endorsed (van Rossum and Schenk, 1984; Trigwell and Prosser, 1991; Newstead, 1992; Gibbs, 1994; Norton and Dickens, 1995, Zimitat and McAlpine, 2003; Pandey and Zimitat, 2007).

Approaches to teaching human anatomy, especially related to the laboratory environment, are constantly evolving to optimize learning and efficiency (see Section 1.2). Accordingly, these changes can be reasonably expected to alter how students approach learning in their new environments (Biggs, 1987). For instance, while one design may motivate students to engage deeply with the associated learning tasks, another may fail
to appear relevant to their development, therefore dissuading them from active participation and causing them to rely more heavily on SAs to learning. These disparate attitudes and their influence on SAL can modulate the quality of the students’ learning and their academic performance (Biggs, 1987). In fact, several studies have demonstrated a link between DAs to learning and higher academic achievement (van Rossum and Schnek, 1984; Trigwell and Prosser, 1991; Newstead, 1992; Gibbs, 1994; Norton and Dickens, 1995; Zimitat and McAlpine, 2003; Pandey and Zimitat, 2007). Furthermore, SAL has been identified as a contributor to students’ long-term ability to recall anatomical knowledge (Dahle et al., 2002; Ward and Walker, 2008; Custers, 2010; Dirkx et al., 2014). Although this evidence suggests that different teaching approaches in human anatomy such as DI, PRO, or CAL may have important downstream effects on acute and long-term outcomes of student learning through SAL, research on educational interventions in human anatomy rarely investigates how SAL is influenced by the resulting environment. As a basic understanding of the human body is a major facet of training competent healthcare professionals, fostering strong retention of anatomical knowledge is arguably the most important goal for basic human anatomy instruction. Accordingly, it is imperative to evaluate how students react to new learning environments through observations of SAL to ensure that the imposed changes promote high-level engagement and meaningful learning. For instance, one study that did investigate SAL in a human anatomy course found that organizing the course according to the principles of constructive alignment promoted DAs to learning (Wang et al., 2013). This type of study exemplifies a research approach that can be used to evaluate teaching interventions and
determine if they are conducive to the qualitative learning goals of a program. When coupled with quantitative assessments of students' academic performance and knowledge retention, the value of an intervention can be more successfully uncovered.

1.3.3 Outcomes of Learning

‘Academic success’ is a widely cited objective of higher education (York et al., 2015). However, the range of outcomes that can characterize academic success in higher education is extremely broad (York et al., 2015). This diversity of approaches has encouraged several reviews aimed at identifying the major outcomes related to academic success and how best to measure learning (Kuh et al., 2006; 2010; York et al., 2015). These reviews have revealed that although academic achievement is the most popular method for evaluating student learning, many other outcomes are held as equally desirable and important to the students’ success (York et al., 2015). Furthermore, since academic grades do not always accurately reflect the quality of a student’s learning or the growth of their cognitive ability, setting such narrow parameters for academic success may result in misleading conclusions from educational research and poorly generalizable findings (Young, 1990; Allen, 2005; Arum and Roska, 2011; York et al., 2015). Accordingly, experimental approaches for measuring learning in higher education should be multifaceted to account for a range of outcomes that contribute to a comprehensive definition of academic success.

1.3.3.1 Academic Achievement

Because of their availability and accessibility to educational researchers, academic grades are the predominant outcome used to measure learning (York et al., 2015). These
grades are intended to serve as an appraisal of a student’s knowledge and understanding of a subject; however, many believe that the factors that contribute to grades are more nuanced, which raises concern about their validity (Allen, 2005; York et al., 2015). When using grades as an outcome for research, it is assumed that the assessment procedures and the assignment of grades accurately reflected and communicated the student’s academic achievement (Snowman and Biehler, 2003). However, if the assessment was improperly designed it may not have evaluated the knowledge that it intended to (Allen, 2005). Furthermore, grades are often used to communicate multiple student achievement criteria using a single value (such as a final grade that is comprised of a myriad of smaller assessments that target different types of achievement) and are therefore vague and not necessarily truthful representations of the student’s achievement in the intended area (Allen, 2005). On the other hand, well designed assessments that are objectively graded can yield valuable and informative quantifications of academic achievement that can be used in the evaluation of educational interventions. Specifically, by breaking larger summative grades into their smaller components and evaluating these more accurate representations of the target achievement criteria, more well-informed conclusions can be drawn from the research findings. For instance, a final course grade may represent a student’s performance on several assessments including written, oral, and practical components. While the written component may evaluate their ability to recall information and therefore characterize their level of knowledge acquisition, the oral component is likely a better reflection of their communication skills and charisma. Furthermore, the practical component may involve a demonstration of technique competency that reflects
their ability to apply knowledge in an authentic task environment. Each of these outcomes represents a different facet of academic success that may be overlooked when examining the final grade as a single outcome. Accordingly, it is sometimes helpful to separate disparate grade components during educational research to gain a more comprehensive and nuanced understanding of student learning through examination of their specific evaluation criteria (York et al., 2015).

1.3.3.2 Skill Acquisition

One outcome that is heralded as a vitally important outcome of higher education, especially in human anatomy, is skill development (Ellis, 2001; Aziz et al., 2002; Granger, 2004; Patel and Moxham, 2006; Kerby et al., 2011; Davis et al., 2014; Bouwer et al., 2016; Rehkämper, 2016; Ghosh, 2017). The anatomy laboratory is considered to be the primary forum in which students will develop transferable skills that they can use in their future careers (Ellis, 2001; Aziz et al., 2002; Granger, 2004; Pawlina and Lachman, 2004; Lachman and Pawlina, 2006; Patel and Moxham, 2006; Pearson and Hoagland, 2010; Kerby et al., 2011; Davis et al., 2014; Fernandes et al., 2015; Bouwer et al., 2016; Rehkämper, 2016; Ghosh, 2017). However, this outcome is considerably difficult to distil into an objective numerical grade. Despite this challenge, outcomes related to the acquisition of critical thinking and other academic skills are among the most frequently used markers of academic success in educational research (York et al., 2015). Several frameworks for evaluating skill development have emerged (many are summarized in York et al., 2015), most of which rely upon self-reported student perceptions of their learning environment. Despite their potential to disguise or misrepresent true effects,
student evaluations are considered to be among the most valid and reliable tools for evaluating ‘soft’ learning outcomes (Ramsden, 1991). Accordingly, these tools include targeted questions that illicit responses that can be used as measures of students’ perceived skill development, which at the very least may approximate their true skill development. For instance, the Course Experience Questionnaire (CEQ) includes a set of questions related to the development of ‘generic skills’ such as teamwork, communication, organization, problem-solving, and critical analysis (Ramsden, 1991). Students are instructed to indicate the degree to which they agree with statements relating to these skills that are voiced in the first person (see Table 1.1). The students’ responses to these questions can be combined to produce a score that ostensibly represents their general skill development in the course (Ramsden, 1991; Griffin et al., 2003).

Table 1.1: Items of the Course Experience Questionnaire related to the Generic Skills scale

<table>
<thead>
<tr>
<th>Targeted Skill</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teamwork</td>
<td>The course helped me to develop my ability to work as a team member.</td>
</tr>
<tr>
<td>Critical analysis</td>
<td>The course sharpened my analytic skills.</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>The course developed my problem-solving skills.</td>
</tr>
<tr>
<td>Communication</td>
<td>The course improved my skills in written communication.</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>As a result of the course, I feel confident tackling unfamiliar problems.</td>
</tr>
<tr>
<td>Organization</td>
<td>The course helped me to develop the ability to plan my own work.</td>
</tr>
</tbody>
</table>

Note. Adapted from Ramsden (1991) and Griffin et al. (2003).
While many researchers are typically cautious about using this type of subjective qualitative data, students’ self-evaluations of their abilities have been shown to align well with their actual abilities (Chemers et al., 2001). However, as academic success is a multifaceted outcome (York et al., 2015), so should it be investigated in multiple ways to ensure that sound conclusions can be drawn from the findings. Accordingly, academic measurements such as performance on presentations and problem-based assessments should be separated and used to evaluate skill acquisition alongside these more subjective variables to ensure that human anatomy students are acquiring the necessary skills and knowledge for success as healthcare professionals in the future.

### 1.3.3.3 Knowledge Retention

While the acquisition of foundational skills is undoubtedly important for future healthcare professionals, maintaining a detailed knowledge and understanding of the fundamental health sciences is also crucial. Despite this importance, anatomical competency of new medical graduates has seen a decline (Cottam, 1999; Waterston and Stewart, 2005; Dickson et al., 2009; Roche et al., 2009; Ahmed et al., 2010; Roche et al., 2011), presenting a vital concern for patient safety (Goodwin, 2000; Ellis, 2002; Older, 2004; Turney, 2007; Ahmed et al., 2010; Singh et al., 2015). Specifically, research on knowledge retention among medical students suggests that nearly 40% of previously learned basic science material is forgotten in the first year after testing (Custers, 2010; Kooloos et al., 2012; Doomernik et al., 2017), while up to just over 80% can be lost in the following five years (DuBois et al., 1969; Blunt and Blizard, 1975; Kennedy et al., 1981). Accordingly, prioritizing research into the influence of novel teaching interventions on
knowledge retention has been strongly suggested in the anatomical sciences (Ward and Walker, 2008; Losco et al., 2017; Vaccarezza, 2018; Wilson et al., 2018).

Knowledge retention can be measured in a myriad of ways. Because there is no 'gold-standard' experimental design for measuring long-term knowledge retention, tests with variable designs administered anywhere from hours to decades after the material was learned can be found in the health sciences education literature (Custers, 2010). One characteristic that unites these studies is that they involve an appraisal of knowledge through recall or recognition, similar to what a student would see in a written course assessment (Custers, 2010). Therefore, the same issues that exist when interpreting academic grades (discussed above) apply when interpreting knowledge retention measures. Accordingly, special attention should be given to the desired outcomes and levels of cognitive complexity when evaluating knowledge retention. Furthermore, proper attention should be placed on potentially mitigating factors that underlie each student’s recall or recognition ability (Theobald and Freeman, 2014). For instance, past studies that have used a variety of research designs have uncovered several factors that influence knowledge retention including sex (Doomernik et al., 2017), study strategies (Roediger and Karpicke, 2006; Karpicke and Blunt, 2011; Logan et al., 2011; Dirkx et al., 2014; Dobson and Linderholm, 2015a; Dobson and Linderholm. 2015b; Meyer et al., 2015; Dobson et al., 2017), and the level of students’ initial engagement with the course content (Onion and Slade, 1995; McManus et al., 1998; Ward and Walker; 2008; Dirkx et al., 2014). Specifically, students who used mnemonics and clinical application exercises have been shown to have higher knowledge recall ability (Meyer et al., 2015), while retrieval
practice and self-testing exercises were also associated with stronger knowledge retention (Roediger and Karpicke, 2006; Karpicke and Blunt, 2011; Logan et al., 2011; Dirkx et al., 2014; Dobson and Linderholm, 2015a; Dobson and Linderholm, 2015b; Dobson et al., 2017). These factors generally relate to the individual student and how they interact with their environment to learn the material, and are ultimately united under the framework of SAL (see Section 1.3.2) (Biggs, 1987). Research on SAL has revealed that health science students who used DAs to learning have higher knowledge recall abilities than those who relied more heavily upon SAs (Onion and Slade, 1995; McManus et al., 1998; Ward and Walker, 2008; Dirkx et al., 2014). These findings indicate that a student’s ability to maintain lasting knowledge and understanding is intimately tied with the initial learning environment and the depth with which they interact with it. Taken together, this illustrates a need to test novel educational interventions to ensure that they contribute to an overall learning environment that supports deep learning and the development of lasting knowledge.

1.4 Conclusion

Human anatomy is currently facing an evolution in the way it is taught. The ever-pressing challenges of limitations to time, cost, and resource availability have encouraged a departure from traditional DI instruction toward less immersive laboratory environments such as PRO. Concomitantly, the rapid growth and sophistication of modern technology has allowed for cost-efficient production of CAL resources and their relatively straightforward inclusion as supplemental tools for human anatomy education. This reshaping of the educational landscape has highlighted a need for careful and accurate
evaluations of novel teaching interventions to ensure that students receive the best possible human anatomy education. This work reviewed two popular teaching interventions in human anatomy, the PRO laboratory and CAL, and discussed evidence-based approaches that can be used to measure student learning in light of these interventions. Due to the amorphous definition of academic success, the best approach to measuring student learning is likely a multifaceted one that acknowledges elements of academic achievement, skill development, and long-term knowledge retention. Furthermore, given the role of SAL in each of these outcomes, factors related to the students' individual characteristics and how they interact with the learning environment should be accounted for in evaluations of novel teaching approaches. Ultimately, since learning is a complicated process, it requires complicated analyses to ensure that students are prepared for their future learning and eventual careers.
2 Rationale, Objectives, and Hypotheses

2.1 Rationale

The relatively recent decline in prevalence of human anatomy education in medical curricula has prompted the rise of supplemental educational interventions that aim to maintain high levels of learning quality while circumventing the time and resource limitations that typically curtail human anatomy courses (Section 1.2). Aside from the dissection-based (DI) laboratory (Section 1.2.1), two of the most popular alternative teaching formats in human anatomy are prosection-based (PRO) laboratories (Section 1.2.2) and supplemental computer-assisted learning (CAL) resources (Section 1.2.3). Although a wealth of research into the pedagogical impact of these resources has emerged over recent decades, the findings are largely limited by issues from quasi-experimental designs, context dependency, and a lack of empirical support. Furthermore, the majority of objective findings in the field use overall academic performance as the primary outcome measure, leaving more qualitative evaluations of the learning process unexamined. Many researchers have called for deeper investigation into alternate measures of student success, including long-term knowledge retention (Losco et al., 2017; Vaccarezza, 2018; Wilson et al., 2018). It is therefore of interest to investigate how the students’ interactions with DI and PRO laboratory environments influence the quantity, quality, and persistence of their learning and to determine the role of CAL resources in that process.

Studies in various fields have uncovered a number of indicators of student success that warrant investigation in educational research. Namely, the depth of each student’s
interaction with the learning environment and its subject matter has been repeatedly linked to desirable outcomes of learning such as performance, higher-order processing, skill development, and knowledge retention (Section 1.3.2). Accordingly, by using the student approach to learning (SAL) framework to examine the relationship between the students’ depth of engagement with the learning process and the aforementioned outcomes within the context of the DI and PRO laboratories and the use of a CAL resource, a more comprehensive understanding of the roles of such teaching approaches in human anatomy can be established.

2.2 Objectives and Hypotheses

The present research began with a curiosity about how learning occurs in the human anatomy laboratory. Specifically, the intent was to compare learning success between students enrolled in DI and PRO laboratory cohorts at the University of Guelph to establish the impact of these popular laboratory designs on human anatomy teaching and to examine the educational influence of introducing a supplemental CAL resource. The overall hypotheses of this thesis are: (1) that the more engaging process of dissection will encourage deeper learning approaches among DI students than PRO students, which will in turn lead them toward more successful learning outcome achievement; and (2) that the use of a novel CAL resource will strengthen students’ foundational knowledge of anatomy and therefore promote more meaningful and lasting learning.

2.2.1 Study One

Research Question: How do SAL and course performance differ between students who participated in either the DI or PRO laboratory environment?
The specific objectives of Study One were to:

1. Compare SAL between students enrolled in DI and PRO and identify how it is influenced by certain demographic characteristics and students’ perceptions of their learning environment;
2. Compare academic performance on written, laboratory-based, and skill-based assessments between DI and PRO students and identify the influence of the laboratory environment and SAL on these outcomes.

Given the objectives of Study One, it was hypothesized that:

1. DI students would report greater proclivity toward deep approaches (DA) to learning in human anatomy than PRO students. However, both groups of students would demonstrate deeper SAL in anatomy than in their general studies;
2. Because of the expected benefits to SAL, DI students would perform better on all academic assessments than PRO students.

2.2.2 Study Two

Research Question: How does the use of a curriculum-targeted CAL resource influence the subjective course experiences (CE), SAL, and academic performance of students enrolled in DI and PRO laboratory cohorts?

The specific objectives of Study Two were to:

1. Compare CE, SAL, and performance between two classes (Fall 2015 and Fall 2016) of DI and PRO students to assess the overall impact of introducing a novel CAL resource into the course;
2. Examine the characteristics of CAL resource use in DI and PRO during the Fall 2016 semester.

3. Investigate the influences of CAL resource use and the students’ satisfaction with the resource on SAL and academic performance in the Fall 2016 semester;

4. Identify students’ perceptions regarding value of the CAL resource and its role in their learning throughout the course.

Given the objectives of Study Two, it was hypothesized that:

1. Students enrolled in the Fall 2016 cohort (who had access to the CAL resource) would have a positive perception of the resource and therefore rate their CE higher, report deeper SAL scores, and ultimately perform better in the course than students from the Fall 2015 cohort;

2. The students who used the CAL resource more frequently and reported higher satisfaction with the tool would also demonstrate higher DA scores and subsequently better academic performance;

3. Students’ perceptions of the CAL resource would be generally positive but would include comments that uncover valuable areas for future modifications and improvements to the tool.

2.2.3 Study Three

Research Question: How does participating in a DI or PRO laboratory and the use of a curriculum-targeted CAL resource influence long-term anatomical knowledge retention?

The specific objectives of Study Three were to:
1. Compare performance on a test of anatomical knowledge recall between DI and PRO students to determine the influences of the laboratory environment on long-term knowledge retention.

2. Compare performance on a test of anatomical knowledge recall between high- and low-frequency CAL resource users to determine the influence of the CAL resource on long-term knowledge retention.

Given the objectives of Study Three, it was hypothesized that:

1. Because of the expected relationship between dissection and DAs to learning, DI students would have stronger anatomical knowledge recall ability than PRO students;

2. Students who used the CAL resource more frequently would develop a stronger initial base of knowledge which would eventually lead to stronger long-term knowledge retention.

The rationale, methodologies, and findings of these studies, as well as a detailed account of the creation of the CAL resource, will be presented in the forthcoming chapters.
3 Evaluating the Influences of the Laboratory Environment on Student Learning

3.1 Chapter Introduction

Dissection- (DI) and prosection-based (PRO) environments are arguably the two most popular laboratory approaches for teaching in human anatomy. Although the relative educational value of these two approaches is often debated, direct comparisons of student learning between the two are rare. A major gap that has been identified in the field is in its collective understanding of how students approach their learning in these environments and what role that plays in their academic success.

The University of Guelph offers an undergraduate human anatomy course that uses both DI and PRO laboratory approaches. These populations were used to conduct a comparison of students’ subjective course experiences (CE), approaches to learning (SAL), and academic performance. The resulting study is described in this chapter and used as a foundation upon which the latter chapters of this thesis are based.

In this study, the demographic profiles and CEs of students enrolled in each laboratory cohort were established and compared. These factors, as well as laboratory enrollment, were examined for their influence on SAL and academic performance using regression statistics. The rationale, methodology, and findings are discussed in Section 3.2. The findings of this study highlighted important considerations for future research and provided a baseline understanding of the course’s educational environment for further studies.
3.2 An Evaluation of Student Learning in Dissection- and Prosection-based Human Anatomy Laboratory Environments
3.2.1 Abstract

Many institutions have transitioned away from traditional cadaver dissection (DI) in human anatomy education, largely due to time and resource limitations. Prosection-based (PRO) laboratories use cadaveric specimens but are less resource-intensive than DI and have therefore become popular alternatives. To facilitate growing enrollment numbers despite low annual cadaver availability, the University of Guelph introduced an ‘enhanced’ PRO laboratory cohort to supplement its existing DI program nearly 10 years ago. All students continued to attend the same lectures and complete the same examinations but now participated in either a DI or PRO laboratory once per week. PRO students studied from the dissections performed by their DI peers, and therefore witnessed a ‘slow reveal’ of structures throughout the course. The aim of this study was to investigate DI and PRO to determine the pedagogical impact of each environment on learning. Specifically, approaches to learning and performance on course assessments were compared between students enrolled in DI and PRO. Multiple linear regression analyses were used to isolate the effect of the laboratory environment on learning from other demographic and situational variables. Participation in DI was significantly positively correlated with deep approaches to learning and grades on laboratory oral assessments; however, both groups had higher mean deep approaches than surface approaches to learning. These findings suggest that the present PRO design may serve as an acceptable method of human anatomy instruction at institutions with limited resources. However, DI may better promote DAs to learning and the development of skills used in oral assessment such as communication, teamwork, and problem-solving.
Keywords: gross anatomy education; undergraduate education; student approaches to learning; student perceptions; deep and surface learning approaches; cadaver dissection; prosection-based laboratories; skill development

3.2.2 Introduction

Human anatomy education, traditionally taught through didactic lectures and cadaver-based dissection (DI) laboratory sessions, relies heavily upon the availability of and access to human cadavers. Since the onset of academic study into the human body, limitations in cadaver availability have been prevalent. In the eras of such pioneering anatomists as Galen, Andreas Vesalius, and Leonardo da Vinci, cadavers were acquired from sources ranging from criminal executions and fallen soldiers, to more nefarious practices including grave robbing, body snatching, and occasionally murder (Ghosh, 2015). While modern human anatomy programs have substituted these disrespectful and illegal practices with more organized and ethical willed-body donation programs, many continue to face challenges in cadaver availability, with the added hindrances of financial deficiencies and curricular time constraints that strain traditional teaching approaches (Drake et al., 2009; Drake et al., 2014; Ghosh, 2017). Accordingly, many institutions are exploring alternative methods of human anatomy instruction that aim to alleviate these pressures. Several approaches have been explored, many of which reduce or entirely remove elements of DI and cadaver use (Aziz et al., 2002; McLachlan et al., 2004; Brenton et al., 2007). However, despite the increased experimentation with alternative styles of human anatomy education, many consider the cadaver to be the persistent gold-standard teaching tool (Cahill and Daley, 1990; Newell, 1995; Yeager, 1996; Jones, 1997;
Dinsmore et al., 1999; Aziz et al., 2002; Older, 2004; Elizondo-Omaña et al., 2005; Patel and Moxham, 2006; Davis et al., 2014; Ghosh, 2017; Flack and Nicholson, 2018).

The University of Guelph (UG) is one institution at which limited cadaver availability and increasing enrollment numbers have impacted the study of human anatomy and the design of its human anatomy program. In the early 2000s, UG offered a DI course to approximately 150 undergraduate students enrolled in their third-year of the Human Kinetics (HK) and Biomedical Sciences (BIOM) majors. At that time, the program used borrowed cadavers from nearby medical schools with established body donation programs for each academic year. Since the laboratory component of the course was dependent upon a surplus of body donation numbers at other schools, the element of DI at UG was threatened annually with cadaver shortages as enrollment grew. To ensure that the increasing number of students would have access to cadaver-based resources despite uncertainty around cadaver availability, a prosection-based (PRO) course was introduced in 2008 that allowed the program to continue to thrive. In this new system, DI students learned by performing dissections on the borrowed cadavers, then the PRO students would study from those specimens (for more detail see Section 3.2.3.2). This change in design allowed the program to increase the course enrollment to more than 200 students in its inaugural year while maintaining consistent cadaver numbers. Over the following decade, a body donation program was established at UG, giving the human anatomy program independence from the surrounding medical schools and allowing it to expand enrollment in the primary course to between 300 and 360 students each cycle.
The PRO cohort has since become integral to the efficiency and sustainability of the human anatomy program at UG.

PRO is among the most commonly implemented laboratory approaches when supplementing or replacing the DI laboratory. While DI requires the student to undertake the time-consuming process of carefully removing skin, fat, and fascial tissue to reveal the structures of interest (muscles, arteries, nerves, etc.), PRO uses previously dissected specimens that allow the student to observe these structures and their spatial relationships. Due to the perceived efficiency of this method, many researchers have challenged the effectiveness and necessity of DI and evaluated the prospect of PRO anatomy instruction as plausible replacement (Nnodim, 1990; Nnodim et al., 1996; Yeager, 1996; Dinsmore et al., 1999; Older, 2004; Granger, 2004; Pawlina and Lachman, 2004; Topp, 2004; McLachlan, 2004; Elizondo-Omaña et al., 2005; Azer and Eizenberg, 2007; Turney, 2007; Winklmann, 2007, Smith et al., 2014; Rehkämper, 2016). However, while the decision to transition from a DI to a PRO approach can be strongly influenced by the desire to reduce cost and increase efficiency, ensuring that the approach fosters optimal student learning and skill development is the primary consideration (McLachlan et al., 2004). DI has been argued to be essential to the development of foundational knowledge such as obtaining a three-dimensional vision of the organization of the human body, gaining appreciation for anatomical variability, and practicing manual skills (Jones, 1997; Marks et al., 1997; Dinsmore et al., 1999; Ellis, 2001; Aziz et al., 2002; Granger, 2004; Burgess and Ramsey-Stewart, 2015). Furthermore, DI is believed to contribute to the development of beneficial social skills including teamwork, professionalism, respect,
and the acceptance of death (Ellis, 2001; Aziz et al., 2002; Granger, 2004; Rehkämper, 2016). Some have argued, however, that PRO laboratories can equally, or better address these intended outcomes at a fraction of the cost and time commitment (Nnodim, 1990; Topp, 2004). PRO also offers benefits to course sustainability – properly preserved and maintained prosections can be used to teach different groups of students for several years at a relatively low cost. In DI, these benefits are lost since cadavers can only be used once, and the burden of acquiring new cadavers for every course cycle is responsible for much of the financial strain associated with DI laboratories (McLachlan et al., 2004).

Since most institutions employ only one type of laboratory design, direct comparisons between DI and PRO environments operating in the same context are rare (see Nnodim, 1990; Dinsmore et al., 1999). This often results in arguments both for and against DI and PRO laboratories that lack objective evaluation of the factors that may affect student learning in the laboratory (Older, 2004). Furthermore, different institutions use PRO designs that are unique to their pedagogical needs, causing research on PRO to be highly context-based and largely irrelevant at other institutions (Wilson et al., 2018). This justifies a call for more thorough descriptions of course designs and investigations into factors that affect how students learn within those environments in modern human anatomy research.

A major factor that has been shown to influence student learning is their intrinsic motivation to understand the topic and the subsequent strategies they use to reach that understanding, commonly referred to as student approach to learning (SAL) (Marton and
Säljö, 1976). SAL is a pedagogical framework constructed to describe the process through which students interact with their environment to reach an acceptable level of understanding of the course content (Marton and Säljö, 1976; Biggs, 1987). Students who implement a ‘deep’ approach (DA) to learning strive to obtain a meaningful and nuanced understanding of the topic through high-level engagement, whereas a ‘surface’ approach (SA) generally involves lower-level engagement strategies, such as rote memorization, that result in a superficial understanding of facts (Marton and Säljö, 1976). Since the use of DAs to learning has been repeatedly tied to greater academic success, skill development, and is generally considered to be representative of meaningful learning, building a learning environment that encourages DAs to learning is widely endorsed (van Rossum and Schenk, 1984; Trigwell and Prosser, 1991; Newstead, 1992; Gibbs, 1994; Norton and Dickens, 1995, Zimitat and McAlpine, 2003; Pandey and Zimitat, 2007).

While the vastly different learning activities encountered in DI and PRO laboratories may influence the students toward stronger DAs or SAs to learning, the environment is not the sole contributor to SAL. Intrinsic factors such as age, sex, and perceived course experience (CE) have been shown to affect SAL and, by extension, academic performance (Entwistle and Tait, 1990; Trigwell and Prosser, 1991; Lizzio et al., 2002; Groves, 2005; Baeten et al., 2010; Rubin et al., 2016). Older students may be more reliant upon DAs and less likely to use SAs than younger students (Groves, 2005; Baeten et al., 2010; Rubin et al., 2016). Similarly, females demonstrate a tendency toward DAs to learning and are less likely to use SAs than males (Rubin et al., 2016). Finally, possessing a positive perception of a course and high interest in the course content has
been shown to promote the use of DAs, while low interest combined with course designs that encourage memorization lead to higher reliance on SAs to learning (Entwistle and Tait, 1990; Trigwell and Prosser, 1991; Lizzio et al., 2002). Considering the pervasive roles of an individual’s demographic profile and perceived CE in determining SAL, those factors should be considered when evaluating different learning environments (Theobald and Freeman, 2014). Therefore, in the debate between DI and PRO, the students’ individual perspectives may merit strong consideration. Some evidence indicates that students may prefer PRO instruction for its efficiency (Dinsmore et al., 1999), while more recent findings have highlighted students’ appreciation for DI as a tool for skill development, as well as anatomy learning (Flack and Nicholson, 2018). More detailed quantification of the perceived and real educational value of DI and PRO course designs may shed light on the most impactful and efficient approach to anatomy education.

It is important to ensure that the chosen approaches to human anatomy education give the students a consistent and powerful learning experience. To adapt to continual pressures from limited resource availability, UG has developed a program design that used both DI and PRO to accommodate a large population of students each academic cycle for the past several years. As the current program design reaches its decennial anniversary, this study aimed to explore factors related to student learning in the DI and PRO laboratory cohorts to evaluate the relative educational impact of each environment. Specific attention was given to how each student’s age, sex, program of study, and CE interacted with their laboratory cohort to influence SAL, and ultimately their performance on written, laboratory, and oral assessments in the course. Examining the influence that
these factors may have on student learning will bring further insight into the effectiveness of the current program at UG, as well as the viability of PRO as an alternate or supplementary method of instruction.

3.2.3 Methods

3.2.3.1 Subjects

The participants in this study were recruited from a third-year introductory human anatomy course at UG. The course is primarily offered to students registered in the HK and BIOM majors, but some students from the Biological Sciences (BIOS) major were also permitted to enroll with instructor consent, given available space. All three of these programs required the same courses in their first two years, apart from individual electives and an introductory biomechanics course in the second year of the HK program. Data collection occurred during the Fall 2015 semester. During that time, all students enrolled in the course (n = 306) attended the same lectures, studied the same content, and completed the same assessments; however, they were registered into either a DI (n = 226) or PRO (n = 80) laboratory cohort. All students voluntarily selected the laboratory cohort in which they wished to enroll.

Institutional review board approval for this study was obtained from the UG Research Ethics Board prior to data collection for this project and all participants indicated informed consent before completing the study protocol.
3.2.3.2 Course Description

Classes in the Fall 2015 semester covered the regions of the back, upper limb, thorax, and abdomen. Within their corresponding laboratory cohort, the students were organized into small groups of seven or eight members. Each DI group was made responsible for the dissection of one side (left or right) of a full-body cadaver throughout the entire semester. Each week, the DI groups participated in a three-hour laboratory session in which they performed dissections of the region discussed in lecture, starting with skin removal, then proceeding to all other aspects of dissection except for bone cuts. In contrast, the PRO groups participated in a two-hour laboratory session each week to study from those dissections and the other available resources (also available to DI students) which included: textbooks, skeletons, professionally dissected specimens, and instructor generated handouts with dissection instructions and important structures to identify. Two or three graduate teaching assistants (TAs) were present in each laboratory session and two upper-year undergraduate students were also available to assist the students if needed. In addition to their regularly scheduled laboratories, all students had access to optional supervised open-laboratory hours throughout the year. In this way, PRO students not only witnessed a slow reveal of structures as they progressed through the semester, they sometimes observed their DI peers performing dissections during the extra laboratory hours. This also meant that PRO students were regularly exposed to partially dissected specimens that required them to manipulate the tissue to find the structures of interest, thereby ‘enhancing’ the PRO experience. It can therefore be generally summarized that the DI students actively performed dissections, while the PRO
students only interacted with previously dissected specimens. All laboratory sessions were coordinated and overseen by human anatomy program staff and faculty.

### 3.2.3.3 Course Assessments

The course assessments came primarily in the form of written examinations and laboratory ‘bell-ringer’ examinations at the midterm (late-October) and final (mid-December) time-points. In addition, students performed one in-laboratory presentation and weekly oral assessments that were graded by the TAs using an instructor-generated rubric (see Table 3.1 for assessment topics and grade weights). Each written test consisted of 25 multiple choice questions and several short-answer questions (25 marks), for a total of 50 marks. The laboratory tests each included 50 ‘bell-ringer’ questions (plus two bonus questions) that required students to identify structures on cadaveric specimens and answer questions about their respective functions or relationships to other structures. For their laboratory presentation, students were divided into subgroups of two or three and assigned to a region (back, upper limb, or thorax and abdomen). During the unit that covered their respective region, the presenters were responsible for delegating duties between their group members and ensuring that each member had learned the necessary content. At the end of the unit, they were required to present the anatomy of the region to their peers in approximately five minutes. After the presentation, the laboratory TAs asked the presenters and their group-members follow-up comprehension and application questions. A group mark out of 20 was assigned to each presenter based on an instructor-generated rubric that emphasized the depth and accuracy of the information presented, the organization of material presented, time management, as well as appropriate and
precise language use and presentation style. For the weekly oral quizzes, the TAs facilitated discussions with each group to solidify content and concepts learned in that week of lecture and laboratory (one mark per individual per laboratory session). Each week, the TAs received a list of recommended questions and topics for these discussions and were asked to minimize their use of improvisation. Together, the presentation assignment and weekly quizzes were intended to foster communication and collaborative learning between students. Therefore, in addition to knowledge and understanding, grading focused on their ability to critically think, problem solve, and formulate answers both individually and as a team.

Table 3.1: Summary of the course assessment measures

<table>
<thead>
<tr>
<th>Assessment Type</th>
<th>Components</th>
<th>Weight (% of final grade)</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Written Tests</strong></td>
<td>Midterm written examination</td>
<td>22.5</td>
<td>Weeks 1-6:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Back</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Upper Limb</td>
</tr>
<tr>
<td></td>
<td>Final written examination</td>
<td>17.5</td>
<td>Weeks 7-12:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Thorax and Abdomen</td>
</tr>
<tr>
<td><strong>Laboratory Tests</strong></td>
<td>Midterm ‘bell-ringer’ examination</td>
<td>22.5</td>
<td>Weeks 1-6:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Back</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Upper Limb</td>
</tr>
<tr>
<td></td>
<td>Final ‘bell-ringer’ examination</td>
<td>17.5</td>
<td>Weeks 7-12:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Thorax and Abdomen</td>
</tr>
<tr>
<td><strong>Laboratory Oral Assessments</strong></td>
<td>Group presentation</td>
<td>10</td>
<td>Present one region in subgroups of 2-3:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Back</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Upper Limb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Thorax and Abdomen</td>
</tr>
<tr>
<td></td>
<td>Weekly laboratory oral quizzes</td>
<td>10</td>
<td>Content related to weekly lecture and laboratory sessions</td>
</tr>
</tbody>
</table>
3.2.3.4 Procedures

Immediately before the first class of the Fall 2015 semester (prior to their first laboratory session), all students enrolled in the course were invited via email to participate in an online survey. The survey package contained a demographic questionnaire (see Demographic Profiles in Section 3.2.3.5) and the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F; see Student Approach to Learning in Section 3.2.3.5). During the first class, the students were given a verbal outline of the online survey, information regarding participation, and the opportunity to ask questions about the study. All 306 students were invited to complete the survey and were offered a 1% bonus grade on their midterm examination as incentive and compensation for their participation. Students were also given the option of completing a short alternate assignment to obtain the bonus grade. The survey was hosted by the online platform, FluidSurveys, and was kept open for ten days, including the first week of the course. One email was sent to remind the students of the invitation to participate prior to closing the survey.

Between the final lecture and final examinations, an invitation to participate in a second survey was sent. As before, all students were invited to participate and given the incentive of a 1% bonus grade on their final examination for their participation, or the option to complete an alternate assignment. This survey package included demographic questions and the R-SPQ-2F, with the addition of the Course Experience Questionnaire (CEQ; see Course Experience in Section 3.2.3.5) and questions about their attendance habits for class and laboratory. The survey was available online via FluidSurveys for ten days and a reminder email was sent prior to its closure.
3.2.3.5 Outcome Measures

Demographic Profiles

Each participant’s age, sex, program of study, year of study, and career goal were collected. To ensure that all participants had the same previous higher education experience, students who were not enrolled in their third year of university were removed from the study (n = 30). Participants reported their career aspirations using an open-format typed response, which were later grouped into four categories for analysis: medical doctor, physical therapy, other, and unsure. The entire ‘other’ category comprised students who stated explicitly health science-related career goals. Class and laboratory attendance habits were self-reported using five-point Likert scales with the following options: ‘Never’, ‘Rarely’, ‘Sometimes’, ‘Often’, and ‘Always’.

Course Experience

The CEQ is a frequently used tool to gauge students’ perceptions of their CE (Ramsden, 1991). It is a validated and reliable tool for evaluating CE using one ‘Overall Satisfaction’ question and 23 additional items that each correspond to one of five scales (Table 3.2): Good Teaching, Generic Skills, Clear Goals and Standards, Appropriate Workload, and Appropriate Assessment (Ramsden, 1991; Wilson et al., 1997). Each item was answered on a Likert-type scale that included five options: ‘definitely disagree’, ‘agree somewhat’, ‘neither agree nor disagree’, ‘agree somewhat’, and ‘definitely agree’. To account for the possibility that students in DI and PRO may have had different perceptions of the resources made available to them, the ‘Learning Resources’ scale (five additional items) from an extended version of the CEQ was also included (Table 3.2)
(Griffin et al., 2003). Students were asked to evaluate their course as a whole, rather than evaluating individual elements of the course or members of the teaching staff. Scores were calculated from participant responses to each of the scales outlined in Table 3.2 as described by McInnis and colleagues (2001).

Table 3.2: Summary of the characteristics addressed by the six scales of the Course Experience Questionnaire

<table>
<thead>
<tr>
<th>Scale</th>
<th>Summary of Characteristics Evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Teaching (six items)</td>
<td>• Attention from the teaching staff&lt;br&gt;• Quality and frequency of instructor feedback, encouragement, and empathy&lt;br&gt;• Instructor enthusiasm and clarity</td>
</tr>
<tr>
<td>Generic Skills (six items)</td>
<td>• Development of teamwork and communication skills&lt;br&gt;• Growth of problem solving and critical thinking</td>
</tr>
<tr>
<td>Clear Goals and Standards (four items)</td>
<td>• Clarity of course expectations and outcomes&lt;br&gt;• Explicitness of goals and quality standards for coursework</td>
</tr>
<tr>
<td>Appropriate Workload (four items)</td>
<td>• Fairness of coursework volume&lt;br&gt;• Availability of time to achieve an appropriate understanding of the assigned coursework</td>
</tr>
<tr>
<td>Appropriate Assessment (three items)</td>
<td>• Testing of higher-order thinking processes rather than rote memory&lt;br&gt;• Evaluating concept understanding rather than facts</td>
</tr>
<tr>
<td>Learning Resources (five items)</td>
<td>• Currency, accuracy, clarity, and availability of course resources&lt;br&gt;• Suitability of resources and their format to fit the course</td>
</tr>
</tbody>
</table>

*Note.* Based on Ramsden (1991) and Griffin et al. (2003).

**Student Approach to Learning**

SAL was measured using the R-SPQ-2F, a shortened version of the Study Process Questionnaire (Biggs, 1987), that includes 20 five-point Likert-type questions to evaluate SAL on ‘deep’ and ‘surface’ scales (Biggs et al., 2001). Participants indicated how closely they identified with statements that corresponded to deep learning motives, deep learning
strategies, surface learning motives, and surface learning strategies. The motive and strategy responses were then combined to produce a respective DA score and SA score for each participant, both with a minimum possible score of 10 and a maximum possible score of 50. A higher score for a given learning approach is indicative of a higher likelihood that the student will use that approach (Biggs et al., 2001). The R-SPQ-2F has been validated for reliability and demonstrates a good fit to its two-factor design (Biggs et al., 2001).

Participants were asked to use the R-SPQ-2F that was included in the first survey to report their attitudes toward their general studying in their first two years of university. These initial responses represented preferred DA (pDA) and SA (pSA) scores (Biggs et al., 2001). In the second survey, participants used the R-SPQ-2F to report their attitudes toward their studies in human anatomy, specifically. These responses therefore represented contextual DA (cDA) and SA (cSA) scores (Biggs et al., 2001). Preferred and contextual DA and SA scores were used to describe learning approaches, evaluate how SAL may be influenced by participation in an intensive laboratory-based human anatomy course, and detect potential differences in SAL between students enrolled in DI and PRO.

**Academic Performance**

Several measures of academic performance were considered in this study. Overall performance was evaluated using final course grades; however, to better elucidate the effects of laboratory environment on specific course outcomes, grades were separated into written, laboratory, and oral components for analyses (Table 3.1). Performance on written tests (WT) was assessed using a combined average of midterm and final written...
examinations. Similarly, laboratory test (LT) performance was evaluated using a combined average of performance on the midterm and final ‘bell-ringer’ examinations. The remaining course assessments included a laboratory presentation and weekly TA-administered oral quizzes at the end of each laboratory session. These two grade categories were combined to reflect oral presentation skills and weekly anatomical competency through performance on in-laboratory oral assessments (LOA).

Cumulative grade averages (CGA) from the first two years of each participant’s undergraduate degree were obtained with permissions from the UG Office of Institutional Analysis and Research and the UG Research Ethics Board.

3.2.3.6 Statistical Analyses

Students who did not complete the full study protocol and participating students who were not enrolled in their third year of university were removed from the study prior to analysis. All data were compiled using Microsoft Excel 2016 and statistical analyses were performed using IBM SPSS Statistics software version 24. Normality was assessed using the Shapiro-Wilk test and visual inspection of Q-Q plots when appropriate. Significance for all tests was declared at $p \leq 0.05$. All data summaries include the mean ($M$) and standard error of the mean ($SEM$) unless otherwise stated.

Demographic Profiles

Age, sex, program of study and CGA were compared between the DI and PRO laboratory cohorts. Mean age was tested using the Mann-Whitney U test for non-parametric data, while sex and program of study distributions were each assessed using
the chi-squared test of independence. Mean CGA was compared between DI and PRO using the independent-samples t-test. These demographic data, as well as career goals and preferred SAL scores, were then loaded as covariates into a binomial logistic regression (BLR) model to determine if they influenced the probability of enrollment in DI or PRO. BLR models jointly consider the influences of multiple independent variables on one categorical dependent variable (in this case, DI or PRO) to identify the strongest contributors to an observed effect. In this study, the BLR model was used to detect any possible population bias between the DI and PRO groups. Self-reported class and laboratory attendance habits were also compared between DI and PRO students using Fisher’s exact test of independence.

Course Experience

CEQ scale scores were calculated according to McInnis and colleagues (2001). First, individual student responses were coded to yield a mean of zero (i.e., 1 = -100, 2 = -50, 3 = 0, 4 = 50, 5 = 100). Since the CEQ includes some questions that are negatively-worded, those items were reverse coded (i.e., 1 = 100, 2 = 50, 3 = 0, 4 = -50, 5 = -100) for analysis. For all resulting scales, goodness of fit and reliability were tested using Cronbach’s α. Finally, scores on each scale were compared between DI and PRO cohorts using the non-parametric Mann-Whitney U test.

Student Approach to Learning

Following the collection of the R-SPQ-2F data, each of the four subscales (deep motive, deep strategy, surface motive, surface strategy) were tested with Cronbach’s α for goodness of fit and reliability. Total DA and SA scores were calculated from these
subscales according to Biggs et al. (2001) and were also tested for goodness of fit and reliability with Cronbach’s $\alpha$. Two separate two-factor mixed analyses of variance (ANOVA) were run to test the interactions between and main effects of learning context (preferred versus contextual SAL scores) and laboratory cohort (DI or PRO) on DA and SA, respectively. To further determine which factors affected SAL scores, cDA and cSA scores were predicted separately using multiple linear regression (MLR) analyses. MLR models are similar to BLR models (described above), except they evaluate a continuous dependent variable instead of a categorical one. MLR analyses were therefore used to determine the relative influences from select demographic variables on contextual SAL.

The pDA and pSA scores were included in the MLR model to control for the learning approaches that the students would typically use in their studies (Biggs et al., 2001; Wang et al., 2013), while CGA was included to control for student aptitude (Theobald and Freeman, 2014). Sex was included in the model since it has previously been found to influence SAL (Rubin et al., 2016); however, age was excluded since all participants fell within a narrow age-range (Table 3.3). Similarly, since HK, BIOM, and BIOS require the same approximate course-load in their first two years (except for individual electives), the program of study category was omitted from the MLR analyses on SAL. CEQ scores and a laboratory environment variable (DI or PRO) were included since they represent situational factors that may affect contextual SAL (Biggs et al., 2001). Finally, the ‘unsure’ career goal variable was included to determine if having a directed goal influenced SAL in anatomy.
Academic Performance

Performance on WTs, LTs, LOAs, and subsequent final grades were each compared between DI and PRO groups using the Mann-Whitney U test for non-parametric data. To determine which factors affected performance in the course, grades on WTs, LTs and LOAs, as well as final grades, were estimated using MLR models that included cDA scores, cSA scores, and laboratory environment as predictor variables. CGA was also included as a variable in each regression model to account for each student’s typical performance (Theobald and Freeman, 2014). Because of the low variability in reported attendance habits, class and laboratory attendance were not included as variables in the MLR models to predict grades. Demographic variables and CEQ scores were acknowledged as manifested in contextual SAL and were therefore excluded from the MLR models for all course performance outcomes (Wang et al., 2013).

3.2.4 Results

3.2.4.1 Demographic Profiles

Subjects

In total, 147 DI students and 44 PRO students (total n = 191) completed both the first and second survey packages. There were no statistically significant differences in mean age, sex, program of study, or CGA between DI and PRO laboratory cohorts (Table 3.3). However, all of these variables remained as potential explanatory variables in the BLR model to predict student choice of enrollment in DI or PRO.
Table 3.3: Summary of demographic profiles within the dissection- and prosection-based laboratory environments of the Fall 2015 human anatomy course at the University of Guelph

<table>
<thead>
<tr>
<th></th>
<th>Laboratory Environment</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dissection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prosection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Number</strong></td>
<td>147</td>
<td>44</td>
<td></td>
<td>191</td>
</tr>
<tr>
<td><strong>Age (M, SD; years)</strong></td>
<td>20.19 ± 0.63</td>
<td>20.16 ± 0.37</td>
<td>0.952</td>
<td>20.18 ± 0.58</td>
</tr>
<tr>
<td><strong>Sex (%)</strong></td>
<td>Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34.0</td>
<td>22.7</td>
<td></td>
<td>0.157</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>66.0</td>
<td>77.3</td>
<td></td>
<td>68.6</td>
</tr>
<tr>
<td><strong>Program of Study (%)</strong></td>
<td>Human Kinetics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>51.7</td>
<td>45.5</td>
<td></td>
<td>50.3</td>
</tr>
<tr>
<td></td>
<td>Biomedical Sciences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>44.2</td>
<td>50.0</td>
<td></td>
<td>45.5</td>
</tr>
<tr>
<td></td>
<td>Biological Sciences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.1</td>
<td>4.5</td>
<td></td>
<td>4.2</td>
</tr>
<tr>
<td><strong>Cumulative Grade Average (M, SD; %)</strong></td>
<td>78.13 ± 7.77</td>
<td>78.86 ± 8.31</td>
<td>0.592</td>
<td>78.30 ± 7.88</td>
</tr>
</tbody>
</table>

*Career Aspirations*

Figure 3.1 provides an overview of the students’ career goals entering third-year. The most common career goal was to become a medical doctor (DI, 42.2%; PRO, 31.8%). Careers in physiotherapy (DI, 14.3%; PRO, 27.2%) and other, mostly health-related, fields (DI, 25.2%; PRO, 20.5%) were also common aspirations, but many were unsure (DI, 18.3%; PRO, 20.5%). A larger proportion of students enrolled in DI aspired to become medical doctors compared to those in PRO; conversely, more PRO students than DI students aimed to become physiotherapists. The ‘other’ and ‘unsure’ career categories were closer in proportion between the different laboratory cohorts. Due to the magnitude of the differences in popularity of the ‘medical doctor’ and ‘physiotherapist’ career goals between DI and PRO, those categories were included as variables in the BLR model to determine their respective influences on the students’ choice of laboratory enrollment (Table 3.4).
Figure 3.1: Career goals of students entering the third-year dissection- and prosection-based human anatomy course at the University of Guelph in the Fall 2015 semester

Demographic Factors and Laboratory Enrollment

Table 3.4 displays the results of the BLR analysis run to predict choice of enrolment in either the DI or PRO cohort. Students who aspired to be physiotherapists were found to be 2.97 times more likely to be enrolled in PRO than students with other career goals ($p = 0.034$); however, no other predictor variables significantly influenced student enrollment at $p \leq 0.05$ (Table 3.4).
Table 3.4: Summary of binomial logistic regression analysis for predictions of laboratory cohort enrollment in Fall 2015

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$SE_B$</th>
<th>Wald</th>
<th>$df$</th>
<th>$p$</th>
<th>Odds Ratio</th>
<th>95% CI for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Preferred Deep Approach Score</td>
<td>-0.013</td>
<td>0.035</td>
<td>0.138</td>
<td>1</td>
<td>0.711</td>
<td>0.987</td>
<td>0.921</td>
</tr>
<tr>
<td>Preferred Surface Approach Score</td>
<td>-0.063</td>
<td>0.034</td>
<td>3.519</td>
<td>1</td>
<td>0.061</td>
<td>0.939</td>
<td>0.879</td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>-0.024</td>
<td>0.028</td>
<td>0.722</td>
<td>1</td>
<td>0.396</td>
<td>0.976</td>
<td>0.924</td>
</tr>
<tr>
<td>Age</td>
<td>-0.042</td>
<td>0.329</td>
<td>0.016</td>
<td>1</td>
<td>0.898</td>
<td>0.959</td>
<td>0.504</td>
</tr>
<tr>
<td>Sex (Female)</td>
<td>-0.427</td>
<td>0.430</td>
<td>0.988</td>
<td>1</td>
<td>0.320</td>
<td>0.652</td>
<td>0.281</td>
</tr>
<tr>
<td>Program of Study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Kinetics</td>
<td>0.920</td>
<td>0.931</td>
<td>0.976</td>
<td>1</td>
<td>0.323</td>
<td>2.509</td>
<td>0.405</td>
</tr>
<tr>
<td>Biomedical Sciences</td>
<td>0.259</td>
<td>0.884</td>
<td>0.086</td>
<td>1</td>
<td>0.770</td>
<td>1.295</td>
<td>0.229</td>
</tr>
<tr>
<td>Career Goal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical Doctor</td>
<td>0.323</td>
<td>0.439</td>
<td>0.544</td>
<td>1</td>
<td>0.461</td>
<td>1.382</td>
<td>0.585</td>
</tr>
<tr>
<td>Physiotherapist</td>
<td>-1.088</td>
<td>0.514</td>
<td>4.470*</td>
<td>1</td>
<td>0.034*</td>
<td>0.337</td>
<td>0.123</td>
</tr>
<tr>
<td>Model Intercept</td>
<td>5.732</td>
<td>7.455</td>
<td>0.591</td>
<td>1</td>
<td>0.442</td>
<td>308.655</td>
<td></td>
</tr>
</tbody>
</table>

Note. Positive $B$ values correspond with enrollment in DI, negative $B$ values correspond with enrollment in PRO. The reference level for sex is male. For program of study and career goal, results represent the listed category compared to the all other categories in that group. $B =$ unstandardized regression coefficient; $SE_B =$ standard error of the coefficient; $p =$ statistical significance of Wald, the asterisk (*) denotes a significant correlation at $p \leq 0.05$.

**Attendance**

Figure 3.2 displays self-reported lecture and laboratory attendance habits throughout the Fall 2015 semester. Reported attendance habits for both the lecture ($p = 0.254$) and laboratory ($p = 0.199$) were not significantly different between students enrolled in DI or PRO (Figure 3.2). In general, students reported higher attendance or the laboratory sessions than they did for lecture (Figure 3.2).
Figure 3.2: Self-reported lecture and laboratory attendance habits of students enrolled in dissection- and prosection-based cohorts at the University of Guelph throughout the Fall 2015 semester

3.2.4.2 Course Experience

The CEQ scales were all found to have good fit and reliability using Cronbach’s $\alpha$ (Table 3.5). The mean scores on all scales were positive (Table 3.5). There were no statistically significant differences in the average ratings between DI and PRO students at $p \leq 0.05$ (Table 3.5).

Table 3.5: Summary of Course Experience Questionnaire scores reported by students enrolled in dissection- and prosection-based cohorts in Fall 2015

<table>
<thead>
<tr>
<th>Scale</th>
<th>Cronbach’s $\alpha$</th>
<th>Dissection $(M, \text{SEM})$</th>
<th>Prosection $(M, \text{SEM})$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Teaching</td>
<td>0.83</td>
<td>54.82 ± 2.97</td>
<td>56.63 ± 4.38</td>
<td>0.955</td>
</tr>
<tr>
<td>Generic Skills</td>
<td>0.82</td>
<td>36.34 ± 2.80</td>
<td>31.06 ± 4.53</td>
<td>0.177</td>
</tr>
<tr>
<td>Clear Goals and Standards</td>
<td>0.85</td>
<td>32.06 ± 3.46</td>
<td>42.05 ± 5.41</td>
<td>0.140</td>
</tr>
<tr>
<td>Appropriate Workload</td>
<td>0.69</td>
<td>32.57 ± 2.76</td>
<td>37.50 ± 4.88</td>
<td>0.274</td>
</tr>
<tr>
<td>Appropriate Assessment</td>
<td>0.58</td>
<td>22.90 ± 2.94</td>
<td>33.33 ± 4.88</td>
<td>0.091</td>
</tr>
<tr>
<td>Learning Resources</td>
<td>0.76</td>
<td>49.12 ± 2.57</td>
<td>53.41 ± 4.09</td>
<td>0.439</td>
</tr>
<tr>
<td>Overall Satisfaction</td>
<td></td>
<td>74.15 ± 3.29</td>
<td>78.41 ± 5.95</td>
<td>0.405</td>
</tr>
</tbody>
</table>
3.2.4.3 Student Approach to Learning

The R-SPQ-2F from both surveys showed good fit and reliability on its deep motive, deep strategy, surface motive, and surface strategy subscales, as well as the combined scales for DA and SA according to Cronbach’s $\alpha$ (Table 3.6).

Table 3.6: Summary of the Revised Two-factor Study Process Questionnaire scale and subscale reliability scores for Fall 2015 students

<table>
<thead>
<tr>
<th>Scale/Subscale</th>
<th>Cronbach’s $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred Deep Approach</td>
<td>0.78</td>
</tr>
<tr>
<td>Deep Motive</td>
<td>0.63</td>
</tr>
<tr>
<td>Deep Strategy</td>
<td>0.62</td>
</tr>
<tr>
<td>Preferred Surface Approach</td>
<td>0.79</td>
</tr>
<tr>
<td>Surface Motive</td>
<td>0.73</td>
</tr>
<tr>
<td>Surface Strategy</td>
<td>0.58</td>
</tr>
<tr>
<td>Contextual Deep Approach</td>
<td>0.80</td>
</tr>
<tr>
<td>Deep Motive</td>
<td>0.70</td>
</tr>
<tr>
<td>Deep Strategy</td>
<td>0.62</td>
</tr>
<tr>
<td>Contextual Surface Approach</td>
<td>0.80</td>
</tr>
<tr>
<td>Surface Motive</td>
<td>0.69</td>
</tr>
<tr>
<td>Surface Strategy</td>
<td>0.66</td>
</tr>
</tbody>
</table>

A two-factor mixed ANOVA found a significant interaction between learning context and laboratory cohort for the dependent variable, SA score [$F(1,189) = 4.31, p = 0.039$, partial $\eta^2 = 0.022$]. The simple main effect of learning context [$F(1,189) = 5.29, p = 0.023$, partial $\eta^2 = 0.027$] was statistically significant, but the simple main effect of laboratory cohort was not [$F(1,189) = 0.53, p = 0.469$, partial $\eta^2 = 0.003$]. Specifically, PRO students had lower cSA scores ($22.68 \pm 0.880$) than pSA scores ($24.82 \pm 0.982; p = 0.020$), while pSA ($23.17 \pm 0.463$) and cSA ($23.06 \pm 0.480$) scores did not significantly differ for DI students ($p = 0.815$) (Figure 3.3).
Figure 3.3: Mean preferred and contextual surface approach scores reported by students enrolled in dissection- and prosection-based laboratory cohorts at the University of Guelph during the Fall 2015 semester

1. Error bars represent the standard error of the mean
2. Letters indicate significant differences at $p \leq 0.05$ (i.e., bars with different letters had statistically significant differences)

The two-factor mixed ANOVA run for the dependent variable, DA score, found no statistically significant interaction between learning context and laboratory cohort [$F(1,189) = 1.77, p = 0.185$, partial $\eta^2 = 0.009$] and no significant simple main effect of laboratory type [$F(1,189) = 1.15, p = 0.285$, partial $\eta^2 = 0.006$]; however, the simple main effect of learning context was statistically significant [$F(1,189) = 10.10, p = 0.002$, partial $\eta^2 = 0.051$]. Specifically, although pDA (32.61 ± 0.833) and cDA (33.41 ± 0.810) scores reported by PRO students did not change ($p = 0.278$), DI students had significantly higher cDA scores (34.95 ± 0.494) than pDA scores (33.01 ± 0.480; $p < 0.0005$) (Figure 3.4).
Figure 3.4: Mean preferred and contextual deep approach scores reported by students enrolled in dissection- and prosection-based laboratory cohorts at the University of Guelph during the Fall 2015 semester

1. Error bars represent the standard error of the mean
2. Letters indicate significant differences at $p \leq 0.05$ (i.e., bars with different letters had statistically significant differences)

The MLR model run to predict cDA score from demographic variables, preferred SAL scores, CEQ scores, and laboratory cohort [$F(13,178) = 17.60, p < 0.0005, R^2 = 0.564$] determined that The Generic Skills ($p < 0.0005$) and Clear Goals and Standards ($p = 0.010$) scales of the CEQ contributed significantly to the prediction of cDA scores (Table 3.7a). Participation in dissection was found to be associated with an increase of 1.474 units on the cDA scale, which was statistically significant ($p = 0.043$). Aside from pDA scores ($p < 0.0005$), no other variables had a significant influence at $p \leq 0.05$ (Table 3.7a).
The MLR model to predict cSA scores from the same list of variables \(F(13,178) = 11.40, \ p < 0.0005, \ R^2 = 0.456\) revealed that scores on the Appropriate Workload \(p = 0.004\) and Appropriate Assessment \(p = 0.003\) scales of the CEQ contributed significantly to the prediction (Table 3.7b). Besides pDA scores \(p = 0.042\) and pSA scores \(p < 0.0005\), no other variables, including laboratory environment \(p = 0.413\), significantly influenced the prediction of cSA scores at \(p \leq 0.05\) (Table 3.7b).
Table 3.7: Multiple regression analyses of the effects of student demographics and course experience on mean learning approach scores in human anatomy for Fall 2015 students

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$SE_B$</th>
<th>$B'$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Contextual Deep Approach Score (dependent)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>15.859</td>
<td>4.470</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Deep Approach Score</td>
<td>0.514</td>
<td>0.060</td>
<td>0.503*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Preferred Surface Approach Score</td>
<td>0.044</td>
<td>0.060</td>
<td>0.044</td>
<td>0.462</td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>-0.048</td>
<td>0.040</td>
<td>-0.064</td>
<td>0.237</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>1.207</td>
<td>0.645</td>
<td>0.096</td>
<td>0.063</td>
</tr>
<tr>
<td>Career Goal (Unsure)</td>
<td>-1.120</td>
<td>0.761</td>
<td>-0.075</td>
<td>0.143</td>
</tr>
<tr>
<td><strong>Course Experience</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good Teaching</td>
<td>-0.002</td>
<td>0.012</td>
<td>-0.013</td>
<td>0.857</td>
</tr>
<tr>
<td>Generic Skills</td>
<td>0.044</td>
<td>0.012</td>
<td>0.249*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Clear Goals and Standards</td>
<td>0.025</td>
<td>0.010</td>
<td>0.175*</td>
<td>0.010*</td>
</tr>
<tr>
<td>Appropriate Workload</td>
<td>-0.004</td>
<td>0.011</td>
<td>-0.025</td>
<td>0.684</td>
</tr>
<tr>
<td>Appropriate Assessment</td>
<td>-0.007</td>
<td>0.010</td>
<td>-0.043</td>
<td>0.469</td>
</tr>
<tr>
<td>Learning Resources</td>
<td>0.018</td>
<td>0.016</td>
<td>0.095</td>
<td>0.240</td>
</tr>
<tr>
<td>Overall Satisfaction</td>
<td>-0.002</td>
<td>0.010</td>
<td>-0.013</td>
<td>0.853</td>
</tr>
<tr>
<td>Laboratory Cohort (Dissection)</td>
<td>1.474</td>
<td>0.724</td>
<td>0.106*</td>
<td>0.043*</td>
</tr>
<tr>
<td><strong>b. Contextual Surface Approach Score (dependent)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>16.109</td>
<td>4.943</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Deep Approach Score</td>
<td>-0.136</td>
<td>0.066</td>
<td>-0.134*</td>
<td>0.042*</td>
</tr>
<tr>
<td>Preferred Surface Approach Score</td>
<td>0.376</td>
<td>0.066</td>
<td>0.379*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>0.059</td>
<td>0.044</td>
<td>0.080</td>
<td>0.183</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>-0.258</td>
<td>0.714</td>
<td>-0.021</td>
<td>0.718</td>
</tr>
<tr>
<td>Career Goal (Unsure)</td>
<td>1.442</td>
<td>0.841</td>
<td>0.097</td>
<td>0.088</td>
</tr>
<tr>
<td><strong>Course Experience</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good Teaching</td>
<td>0.012</td>
<td>0.014</td>
<td>0.072</td>
<td>0.371</td>
</tr>
<tr>
<td>Generic Skills</td>
<td>-0.025</td>
<td>0.013</td>
<td>-0.140</td>
<td>0.060</td>
</tr>
<tr>
<td>Clear Goals and Standards</td>
<td>-0.007</td>
<td>0.011</td>
<td>-0.048</td>
<td>0.529</td>
</tr>
<tr>
<td>Appropriate Workload</td>
<td>-0.035</td>
<td>0.012</td>
<td>-0.200*</td>
<td>0.004*</td>
</tr>
<tr>
<td>Appropriate Assessment</td>
<td>-0.033</td>
<td>0.011</td>
<td>-0.197*</td>
<td>0.003*</td>
</tr>
<tr>
<td>Learning Resources</td>
<td>0.005</td>
<td>0.017</td>
<td>0.025</td>
<td>0.782</td>
</tr>
<tr>
<td>Overall Satisfaction</td>
<td>-0.008</td>
<td>0.011</td>
<td>-0.052</td>
<td>0.504</td>
</tr>
<tr>
<td>Laboratory Cohort (Dissection)</td>
<td>0.656</td>
<td>0.800</td>
<td>0.048</td>
<td>0.413</td>
</tr>
</tbody>
</table>

**Note.** The reference levels for categorical variables are male, all other career goals, and prosection. $B = \text{unstandardized regression coefficient; } SE_B = \text{standard error of the coefficient; } B' = \text{standardized coefficient; } p = \text{statistical significance of } B'$, asterisks (*) denote significance at $p \leq 0.05$.

3.2.4.4 Academic Performance

**Written Tests**

No significant difference in mean WT grades was observed between DI (85.29% ± 0.701) and PRO (84.70% ± 1.284) students ($p = 0.606$) (Figure 3.5). The MLR model to
predict WT grades from CGA, contextual SAL scores, and laboratory environment \[F(4,186) = 46.78, p < 0.0005, R^2 = 0.501\] revealed that CGA \(p < 0.0005\) and cSA scores \(p = 0.013\) added significantly to the prediction of WT grades. However, neither cDA scores \(p = 0.243\) nor laboratory environment \(p = 0.317\) contributed significantly to the prediction. Regression coefficients and standard errors can be found in Table 3.8a.

**Laboratory Tests**

There was no significant difference in mean LT grades between DI \(87.84\% \pm 0.865\) and PRO \(87.20\% \pm 1.468\) students \(p = 0.563\) (Figure 3.5). The MLR model used to predict LT performance from CGA, cDA and cSA scores, and participation in DI or PRO \[F(4,186) = 34.63, p < 0.0005, R^2 = 0.427\] identified that CGA \(p < 0.0005\) and cSA scores \(p = 0.022\) contributed significantly to the prediction of LT grade, while cDA scores \(p = 0.066\) and laboratory environment \(p = 0.464\) were not significantly correlated with LT grades at \(p \leq 0.05\). Regression coefficients and standard errors are displayed in Table 3.8b.

**Laboratory Oral Assessments**

DI students performed significantly better on LOAs than PRO students \(\text{DI} = 91.96\% \pm 0.357, \text{PRO} = 87.09\% \pm 0.829, p < 0.0005\) (Figure 3.5). The MLR model to predict LOA grades from CGA, cDA and cSA scores, and laboratory environment \[F(4,186) = 12.65, p < 0.0005, R^2 = 0.214\] found that CGA was significantly associated with LOA grades \(p = 0.001\); however, cDA \(p = 0.442\) and cSA scores \(p = 0.674\) were not significant predictors. Accordingly, participation in DI was found to be associated with
a 4.89% increase in LOA grades \((p < 0.0005)\). See Table 3.8c for regression coefficients and standard errors.

**Final Grade**

Overall, final grades did not significantly differ between DI (DI = 87.77% ± 0.605) and PRO (PRO = 86.27% ± 1.094) students \((p = 0.207)\) (Figure 3.5). The MLR model to predict final grades using CGA, cDA and cSA scores, and laboratory environment \([F(4,186) = 51.58, p < 0.0005, R^2 = 0.526]\) revealed that CGA was a significant predictor of final grades in the course \((p <0.0005)\). Students’ cDA scores \((p = 0.091)\) were not significant predictors at \(p \leq 0.05\), but cSA scores \((p = 0.011)\) were. Participation in DI was associated with an increase of 1.84% in final grades \((95\% CI = 0.097, 3.588; p = 0.039)\). Regression coefficients and standard errors are available in Table 3.8d.
Figure 3.5: Mean grades on written tests, laboratory tests, laboratory oral assessments, and final grades of students enrolled in dissection- and prosection-based laboratory cohorts at the University of Guelph during the Fall 2015 semester

1. Error bars represent the standard error of the mean
2. The asterisk (*) denotes a significant difference between dissection- and prosection-based groups at \( p \leq 0.05 \)
### Table 3.8: Multiple regression analyses of the effects of laboratory cohort enrollment and student approach to learning on course performance for Fall 2015 students

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$SE_B$</th>
<th>$B'$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Written Test Grade (dependent)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>29.359</td>
<td>6.172</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>0.721</td>
<td>0.056</td>
<td>0.670*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.097</td>
<td>0.082</td>
<td>0.067</td>
<td>0.243</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>-0.210</td>
<td>0.083</td>
<td>-0.144*</td>
<td>0.013*</td>
</tr>
<tr>
<td>Laboratory Cohort (Dissection)</td>
<td>1.053</td>
<td>1.050</td>
<td>-0.052</td>
<td>0.317</td>
</tr>
<tr>
<td><strong>b. Laboratory Test Grade (dependent)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>24.118</td>
<td>8.038</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>0.788</td>
<td>0.073</td>
<td>0.603*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.199</td>
<td>0.107</td>
<td>0.133</td>
<td>0.066</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>-0.250</td>
<td>0.108</td>
<td>-0.141*</td>
<td>0.022*</td>
</tr>
<tr>
<td>Laboratory Cohort (Dissection)</td>
<td>1.003</td>
<td>1.368</td>
<td>0.041</td>
<td>0.464</td>
</tr>
<tr>
<td><strong>c. Laboratory Oral Assessment Grade (dependent)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>74.089</td>
<td>4.612</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>0.137</td>
<td>0.042</td>
<td>0.214*</td>
<td>0.001*</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.048</td>
<td>0.062</td>
<td>0.055</td>
<td>0.442</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>0.026</td>
<td>0.062</td>
<td>0.030</td>
<td>0.674</td>
</tr>
<tr>
<td>Laboratory Cohort (Dissection)</td>
<td>4.893</td>
<td>0.785</td>
<td>0.409*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td><strong>d. Final Grade (dependent)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>36.720</td>
<td>5.199</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>0.630</td>
<td>0.047</td>
<td>0.678*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.118</td>
<td>0.069</td>
<td>0.094</td>
<td>0.091</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>-0.179</td>
<td>0.070</td>
<td>-0.142</td>
<td>0.011*</td>
</tr>
<tr>
<td>Laboratory Cohort (Dissection)</td>
<td>1.842</td>
<td>0.885</td>
<td>0.106*</td>
<td>0.039*</td>
</tr>
</tbody>
</table>

**Note.** The reference level for the laboratory cohort variable is prosection. $B$ = unstandardized regression coefficient; $SE_B$ = standard error of the coefficient; $B'$ = standardized coefficient; $p$ = statistical significance of $B'$, asterisks (*) denote significance at $p \leq 0.05$.

### 3.2.5 Discussion

To accommodate for high enrollment numbers despite restrictions in curricular time, financial support, and cadaver availability, many institutions use PRO as a less resource-intensive alternative to traditional DI in human anatomy education (McLachlan et al., 2004). The present study examined a two-tiered DI and ‘enhanced’ PRO design that has enabled UG to increase its human anatomy course enrollment capacity and overcome limitations to cadaver access. DI and PRO were compared to determine how the demographic factors and course satisfaction of students in each cohort influenced
their SAL and subsequent academic performance on course assessments. The CEQ results suggest that both the DI and ‘enhanced’ PRO cohorts were well-received by participating students (Table 3.5) and led to comparable academic performance outcomes (Table 3.8); however, DI may have better fostered the use of DAs to learning and skill development (Table 3.7a; Figure 3.5; Table 3.8c). These findings contribute objective data to the persistent debate surrounding DI and PRO laboratory environments in human anatomy education.

Encouraging independent students who use DAs to learning is a universal goal of higher education institutions (Wilson and Fowler, 2005). It is well established that DAs to learning should be widely endorsed as they are considered to be conducive to meaningful learning, while SAs such as the memorization and regurgitation of facts represent less desirable behaviours (Marton and Säljö, 1976; van Rossum and Schenk, 1984; Trigwell and Prosser, 1991; Newstead, 1992; Gibbs, 1994; Norton and Dickens, 1995, Zimitat and McAlpine, 2003; Pandey and Zimitat, 2007). Although DI and PRO students did not differ in direct comparisons of SAL in this study, the analyses identified important trends that suggested strong benefits associated with DI laboratory environments. For instance, DI students had significantly higher cDA scores than pDA scores, whereas cDA and pDA did not differ for PRO students (Figure 3.4). This suggests that participation in the course promoted the development of deeper learning strategies for DI students (Biggs, 1987; Biggs et al., 2001; Wang et al., 2013). Furthermore, a significant relationship between DI and DAs to learning was uncovered in the MLR analyses (Table 3.7). Because the MLR analyses in question were used to predict cDA scores while controlling for many
potentially confounding variables, including students’ preferred SAL scores, these findings suggest that participation in DI had a direct role in the observed increases to DA scores. While many anatomy educators assert that DI promotes outcomes typically associated with DAs to learning (Bergman, 2015; Ghosh, 2017), quantitative evidence of this link akin to the findings of this study has not yet been reported in the human anatomy education literature (to the best of the authors’ knowledge). In fact, the rarity of substantive data to support such claims is generally acknowledged by the anatomy education academic community (Cahill et al., 2000; Reidenberg and Laitman, 2002; Older, 2004; Bergman et al., 2014; Bergman, 2015; Ghosh, 2017). These findings suggest that DI laboratories should be the primary method of instruction at institutions that can afford the time and resources to support it.

One of the strongest assertions that has been used to link DI to DAs to learning is that DI contributes to the development of transferrable skills (Ellis, 2001; Aziz et al., 2002; Granger, 2004; Pawlina and Lachman, 2004; Lachman and Pawlina, 2006; Patel and Moxham, 2006; Pearson and Hoagland, 2010; Kerby et al., 2011; Fernandes et al., 2015; Davis et al., 2014; Bouwer et al., 2016; Rehkämper, 2016; Ghosh, 2017). Such claims therefore imply that the development of beneficial skills such as professionalism, teamwork, and communication may result from enhancements to the learning process related to specific activities encountered in the DI laboratory (Biggs et al., 2001). Skill development is difficult to objectively quantify; however, this study used LOA performance as a collective proxy measure for various skills related to oral presentation. For this measure, students in both laboratory cohorts were graded according to the same rubric
that emphasized organization, critical thinking, problem solving, communication, and teamwork. Overall, DI students outperformed PRO students on LOAs by 4.6% (Figure 3.5) which suggested that participation in DI may have encouraged the development of oral presentation skills such as these. This trend, however, was not accompanied by any significant correlations between the contextual SAL scores and LOA grades, indicating that SAL had no influence on LOA performance. In fact, none of the available data except for CGA and participation in DI shared any correlation with LOA performance (Table 3.8c). Therefore, while it appears that a relationship between participation in DI and improved skill development exists, the mechanism behind these changes is unclear. However, further indications of a potential relationship between DI and skill development were revealed through analyses of student perceptions of the course. The Generic Skills scale of the CEQ was used to quantify perceived skill development using student agreement ratings (Ramsden, 1991). This scale comprised items that asked the students to rate how their participation in the course helped to develop their skills in teamwork, analysis, problem-solving, communication, and planning, as well as their confidence in facing unfamiliar problems (Ramsden, 1991). Although the differences between DI and PRO were statistically non-significant, the Generic Skills scale was the only course evaluation criteria for which DI students reported higher mean scores than PRO students (Table 3.5). Furthermore, both participation in DI and scores on the Generic Skills scale were significantly positively predictive of cDA scores. Therefore, although cDA score itself was not significantly correlated with LOA grade, taken together, these findings further suggest a potential relationship between participation in a DI laboratory, skill development, and
improvements in deep learning. These data suggest that DI may provide the optimal
environment for learning human anatomy when time and resources permit its inclusion.

While the results of this study support the use of DI laboratory environments, the
value of PRO was not discredited by the findings. For example, DI and PRO cohorts did
not have significantly different cSA or cDA scores in direct comparisons between the
groups (Figures 3.3 and 3.4). While the direct comparisons do not account for other
potential mitigating factors (i.e., demographic variables), they did suggest that the present
‘enhanced’ PRO design was not inferior to DI. Furthermore, although SA and DA scales
do not share a direct inverse relationship (i.e., an individual student can have high scores
on both the DA and SA scales) (Biggs et al., 2001), the sheer magnitude of difference
between the mean DA and SA scores reported in this study was worthy of note (Figures
3.3 and 3.4). Students in both DI and PRO reported far higher cDA scores (Figure 3.4)
than cSA scores (Figure 3.3), and PRO students had significantly lower cSA scores than
pSA scores (Figure 3.4). These results indicated that the ‘enhanced’ PRO environment
described in this study was somewhat successful at supporting the students’ DAs, rather
than SAs to learning, compared to their studies in general (Biggs et al., 2001; Wang et
al., 2013). This appearance of near pedagogical equivalence between the DI and
‘enhanced’ PRO designs was also echoed in the analyses of performance on course
assessments. Despite disparate laboratory time commitments and levels of laboratory
interactivity between DI and PRO, no significant difference in final grades was observed
between the two groups (Figure 3.5). This implied that both groups had equal
opportunities for knowledge acquisition. Again, however, the findings of these direct
comparisons do not represent all aspects of the learning context. Nonetheless, various other studies that have used performance outcomes as indicators of successful learning in DI and PRO have found similar results and used them to suggest that DI and PRO are equally conducive to student learning (Nnodim, 1990; Nnodim et al., 1996; Dinsmore et al., 1999; Winklemann, 2007; Ashdown et al., 2013). Focusing exclusively on performance in this way neglects the less tangible learning outcomes that may have been encouraged by the laboratory environment such as DAs learning and skill development. Moreover, while equal performance may suggest that the both designs were conducive to short-term knowledge acquisition and the lack of a statistically significant difference in the SAL may suggest equal learning quality between the groups, these specific findings do not adequately account for the mitigating and potentially confounding factors, including students’ demographic profiles and CEs. It is also important to consider how the specific design of the ‘enhanced’ PRO laboratory at UG differs from traditional PRO laboratories (Wilson et al., 2018) and how that may have lessened the magnitude of the observed differences between DI and PRO.

The similarities and differences between the DI and ‘enhanced’ PRO laboratories may have had a more direct effect on the students’ perceptions of and satisfaction with their respective learning environment. Based on the overwhelmingly high scores on the CEQ scales and overall course satisfaction ratings, the students indicated that they perceived both laboratory types offered fair, rewarding, and enjoyable learning experiences. This finding was generally expected in an immersive course such as this. Providing students with new learning activities has been demonstrated to boost student
interest and increase their engagement (Leach and Zepke, 2011; Larkin and McAndrew, 2013). Accordingly, the novel experience of the cadaver laboratory, especially DI, is generally highly anticipated by students and is often heralded as a rite of passage for budding healthcare professionals (Dinsmore et al., 1999; Larkin and McAndrew, 2013). UG is among very few institutions in Canada that offer full-body cadaver DI opportunities to non-medical undergraduate students, and many who enroll in the HK and BIOM degree programs do so specifically for this curricular feature. Students were therefore likely to have been excited for the opportunity to participate in the laboratory component of the course. In addition, since they typically have had limited to no experience with death or exposure to cadavers upon entering the course, interacting with a full-body cadaver may have provided enough novelty and fulfilment to elicit deep engagement and high satisfaction scores from both DI and PRO students (Leach and Zepke, 2011; Wilson et al., 2018).

Although the high satisfaction among both groups is reassuring, there may be more nuanced differences between them that influenced their SAL. While curricular time limitations are powerful factors that push many institutions away from the use of DI programs (Turney, 2007), such issues may also influence the students’ own preferences of learning environment and impact their subsequent course satisfaction. For instance, while DI is generally seen as conducive to knowledge reinforcement, some students have cited the time-intensive nature of DI as a barrier that discourages their participation (Dinsmore et al., 1999; Whelan et al., 2018). Given the choice between DI and PRO, these students preferred PRO as a more efficient use of their study time (Dinsmore et al.,
Similarly, students in the present study were given the choice to enroll in either DI or PRO at the onset of the course. Some students in this program may have viewed the laboratory component as a restriction to their time for individual study outside of the laboratory. Since the PRO laboratories were one hour shorter in duration, such students may have chosen PRO to thereby reduce their weekly academic commitment. This strategy may explain why students who aspired to study physical therapy were more likely to enroll in PRO compared to their peers with other career goals. Although speculative, it is possible that aspiring physical therapists saw DI experience as unnecessary for their future success and therefore opted for the cohort with a shorter time commitment. However, it must be noted that enrollment in DI was still very high, nearly triple that of PRO, indicating that the time commitment of DI is not a strong deterrent for most students. Irrespective of their motives, millennial students have been shown to value having a choice in the delivery method of their anatomy education (Whelan et al., 2018). Therefore, offering these students a choice between DI and PRO may have ultimately contributed to the high course satisfaction ratings reported by both cohorts and subsequently influenced the depth of their learning and success in the course.

3.2.5.1 Limitations

As with most educational research in human anatomy, this study was subject to various potential limitations. Primarily, this study only addressed the educational context at one specific institution. Although as many confounding factors as possible were accounted for, it is unclear whether these same findings would be replicated at other institutions with students at different degree levels and career stages. Furthermore, while
traditional DI laboratories are relatively uniform across institutions, PRO laboratories tend to have less consistent designs (Wilson et al., 2018). Because separate institutions often have unique definitions of PRO designed to fit their own educational context, comparisons between DI and PRO can yield findings that are institution-specific and difficult to generalize (Wilson et al., 2018). In this case, PRO participants observed the gradual reveal of structures through peer-created dissections, which were sometimes only partially finished. Accordingly, PRO students were sometimes required to actively search for structures to observe and appreciate their relationships. Because of the associations between multisensory hands-on environments and meaningful learning (Kolb, 1984; Trigwell and Prosser, 1991; Michael, 2006; Ward and Walker, 2008; Kauffman and Mann, 2010), this additional exploratory learning component of the 'enhanced' PRO may have caused the differences in SAL scores between cohorts to be less pronounced than if the PRO laboratories were run using professionally prepared specimens, as is the case at many other institutions.

Furthermore, not all students participated in the study (DI = 65%, PRO = 55%), so there was a possibility of selection bias between those students who completed the surveys and those who opted not to participate. This could be a result of the grade-based incentives to participate. Although their cumulative worth was only 0.4% of the final grade, it is possible that the more driven students were more motivated to participate in order to receive the extra grades, thus inducing a selection bias. However, follow-up analyses found no significant differences in CGA, program of study, or laboratory enrollment type between participating and non-participating students (data not shown). Some students
were also removed from the study because they were not enrolled in their third year of university \((n = 30)\). This was performed to normalize the presage factors across students for accurate comparisons of SAL and depict the target demographic of the third-year course as closely as possible, so it was therefore unlikely to confound the findings (Biggs et al., 2001). Ultimately, since SAL was self-reported, it is possible that the students did not accurately report their preferred or contextual motivations and strategies for learning.

The extra laboratory hours present the primary factor that could have potentially confounded the results of this study. These hours were open to both DI and PRO students throughout the semester for in-laboratory studying or extra dissection work. Unfortunately, attendance was not consistently or accurately tracked during these time-slots while the study was underway. Consequently, it is possible that DI and PRO students had different rates of extra laboratory attendance and contact time with the cadavers, leading to subsequently different levels of comfort in the laboratory environment between groups. This may have influenced their relative confidence in oral presentations, ultimately leading to disparate LOA grades (Bergman et al., 2008). Anecdotally, DI students typically have high extra laboratory attendance rates; however, PRO students also frequently attend these hours for the opportunity to study from the specimens and other available laboratory resources. Regardless, this factor should be accounted for in future studies. Finally, LOA grades were assigned as group marks, making this grade category less specific and more subjective than the WTs and LTs. It is therefore possible that different trends would emerge if LOAs were structured as individual assessments. However, the marking was done consistently by the same course TAs using identical rubrics between DI and PRO
cohorts. This course element and its marking design have been maintained to promote teamwork and collaborative working skills in the course.

3.2.5.2 Future Directions

While this study contributes empirical data to support the notion that skill development and deep learning have stronger associations with participation in DI than PRO, it is rooted in the educational context of UG. More research is required to isolate the specific characteristics that promote these beneficial outcomes in learning environments with different contexts. Further research is also required to determine which learning environment best prepares students for the challenges they will face in advanced degree programs and their future careers.

Improving the course design was not a primary objective of this study; however, some of the results hinted at certain areas that could benefit from changes to the course structure (not exclusive to DI or PRO). Principally, associations were uncovered between SAs to learning and scores on the Appropriate Workload and Appropriate Assessment scales of the CEQ (Table 3.7b). This meant that students who felt that the course workload was too heavy and fast paced and those who felt that the testing put too strong of a focus on factual recall and recognition used more SAs (Ramsden, 1991). Since, cSA scores were associated with poorer performance on WTs (Table 3.8a) and LTs (Table 3.8b), this suggests that the students’ negative perceptions of the different course elements may have hindered their learning in the course. Conversely, scores on the Clear Goals and Standards scale of the CEQ were significantly positively correlated with cDA scores, indicating that understanding the instructor’s expectations allowed students to
interact more deeply with the course content. Combined, these trends support the widely accepted notion that aligning the course goals, activities, and assessment practices to target high order learning outcomes can help to both reduce the students’ reliance on SAs and encourage deep learning behaviours (Cohen, 1987; Biggs and Tang, 2011; Wang et al., 2013). Although the evidence suggests that courses should aim to encourage DAs to promote high quality learning instead of suppressing SAs to learning (Trigwell and Prosser, 1991), attention should be taken in future cohorts to identify and improve course elements that may be associated with SAs to learning. Regardless of laboratory design, alignment should therefore be a priority during the overall course design process.

3.2.6 Conclusions

Laboratory-based human anatomy education has long been challenged by resource and time limitations. This work analyzed the factors that affected learning within the DI and ‘enhanced’ PRO cohorts that were designed to allow UG to run an efficient and sustainable laboratory-based human anatomy course despite cadaver limitations and large student numbers. Participation in DI was significantly positively associated with DAs to learning and may have encouraged the development of skills used in oral presentation. However, both laboratory types were effective at maintaining a high level of student satisfaction, higher DA than SA scores, and statistically equivalent test performance. Other institutions may therefore be able to use this ‘enhanced’ PRO design to alleviate administrative challenges and allow students to choose the environment that best suits their learning goals without drastically compromising learning quality.
4 Evaluating the Influence of a Computer-assisted Learning Resource on Student Learning in Human Anatomy

4.1 Chapter Introduction

The use of computer-assisted learning (CAL) tools for supplementing traditional teaching in human anatomy is becoming increasingly popular. Several studies have emerged that reported students’ use and perceptions of these resources and examined student performance as an outcome; however, the capacity of student performance to evaluate learning quality is debated. Conversely, changes in student’s approaches to learning (SAL) have become a more widely used to measure meaningful learning. Few studies, however, have used the SAL framework to assess the influences of novel CAL resources on the learning environment in human anatomy.

The human anatomy program at the University of Guelph was interested in promoting self-directed learning in the laboratory to improve the students’ engagement and learning quality. Accordingly, a novel CAL resource was created and introduced during the Fall 2016 semester to supplement the dissection- (DI) and prosection-based (PRO) laboratory environments by bridging the concepts discussed in lecture with the content encountered in the laboratory. This chapter will present the theoretical and technical considerations that informed the creation of the resource and describe a study conducted to evaluate its influence on student learning in human anatomy.

The previous chapter presented a study that assessed student learning in the DI and PRO environments to find that participation in dissection encouraged deep approaches to learning and may have improved skill development. This chapter examined
the DI and PRO cohorts in isolation to determine how students’ use of the novel CAL resource influenced their approaches to learning and performance in the course. Ultimately, the findings uncovered important insights into CAL use in human anatomy and highlighted crucial considerations for its future development.
4.2 Creation of a Curriculum-targeted Computer-assisted Learning Resource for Human Anatomy Education

4.2.1 Introduction

Human anatomy is a fundamental science in medical and health-related fields. Despite this importance, curricular hours devoted to the study of human anatomy have suffered a decline over recent decades (Drake et al., 2002; Drake et al., 2009; Drake et al., 2014; Craig et al., 2010). This reduction in allotted time has been partly attributed to unbalanced student to demonstrator ratios, reattribution of curricular time to other disciplines, and the large costs involved with running a laboratory course (McLachlan et al., 2004; Turney, 2007; Drake et al., 2009; Drake et al., 2014). To maintain anatomical fluency among students of the medical and health sciences, the methods by which anatomy is taught in higher-education have subsequently been forced to adapt and evolve to combat these extrinsic pressures. Specifically, rapid advancement in digital imaging technology has allowed many educators to turn to computer-assisted learning (CAL) to supplement their courses and reduce the cost and time investments associated with their existing anatomy programs (Elizondo-Omaña et al., 2005; Granger and Calleson, 2007; Adamczyk et al., 2009; McNulty et al., 2009; Johnson et al., 2012; Wright, 2012; Barbeau et al., 2013; Topping, 2014; Attardi and Rogers, 2015; Losco et al., 2017). With growing reliance upon these alternative resources, it is important to identify the characteristics that optimize the quality of these resources and maximize their positive impact on student learning.
While the ideal contexts for the implementation of CAL remain unclear (Bergman, 2015; Vaccarezza, 2018), the available evidence suggests that CAL resources can generally improve learning in the anatomical sciences (Losco et al., 2017). For example, CAL has been shown to benefit knowledge acquisition, leading to higher academic performance when used either independently or in conjunction with traditional teaching methods (Qayumi et al., 2004; Glittenberg and Binder, 2006; Nicholson et al., 2006; Venkatiah, 2010; Pani et al., 2014). These benefits appear to have originated from students’ positive perceptions toward CAL tools (Glittenberg and Binder, 2006; Venkatiah, 2010; Codd and Choudhury, 2011; Hopkins et al., 2011; Stirling and Brit, 2014), which themselves may impact student approach to learning (SAL) (Marton and Säljö, 1976; Biggs, 1987). SAL is a framework that is used to describe the level of student engagement with the learning process on ‘deep’ approach (DA) and ‘surface’ approach (SA) scales (Biggs, 1987; Biggs et al., 2001). However, as a product of the interaction between the individual student and their learning environment, these scores are flexible and can vary depending on the context (Biggs, 1987). Accordingly, each student’s personal characteristics (age, sex, etc.) and how they perceive their learning environment and its resources can ultimately influence the depth of their learning approaches in a course (Biggs, 1987). Therefore, if CAL elicits stronger student satisfaction with the learning environment, it may promote DAs to learning overall (Biggs, 1987). Furthermore, since CAL resources are typically used alone or in small groups, students may use such resources for self-directed learning, which has also been shown to foster DAs to learning (Reeves et al., 2004; Findlater et al., 2012; Brophy, 2013). Therefore, while research
examining the relationship between CAL and SAL is sparse, the apparent improvements to academic performance and positive attitudes exhibited toward CAL from students indicate that it may provide some benefits to overall student learning.

In an attempt to promote self-directed learning behaviours and maximize the impact of the laboratory environment, a novel cadaver-based CAL resource was designed for use in the undergraduate dissection- (DI) and prosection-based (PRO) human anatomy course at the University of Guelph (UG). The following sections will discuss both the theoretical and technical considerations associated with the design, creation, and implementation of this resource. The units and sections included final version of the CAL resource are available in Appendices A – H.

4.2.2 Human Anatomy at the University of Guelph

UG offers a full-body introductory laboratory-based human anatomy course in the third-year of the Human Kinetics and Biomedical Sciences majors. The course is divided across two semesters, covering half of the body regions in each semester. The CAL resource discussed herein was designed to target content covered in the fall semester of the course which included regional instruction of the back, upper limb, thorax, and abdomen.

The course is intended to communicate a detailed understanding of the relevant osteology and musculature that make-up the framework of each region before exploring the pathways and relationships of related neurovascular structures in further depth and solidifying the content in applied or clinical contexts. Therefore, the lecture component is
primarily used to cover the fundamental information of each region using traditional textbook images and drawing activities, while the weekly cadaver-based laboratories allow students to identify structures, visualize their relationships, and explore the content in a hands-on environment.

Upon registering into the course, the students choose to participate in either a DI (one three-hour session per week) or PRO (one two-hour session per week) laboratory section; however, all students attend the same lectures (three one-hour lectures per week) and complete the same course assessments. In both DI and PRO, the students are organized into small groups of seven or eight. Each DI group is made responsible for the dissection of one side (left or right) of a full-body cadaver throughout the entire semester. Each week, the DI groups complete detailed dissections of the region discussed in lecture and study from the other available resources such as textbooks, skeletons, and prosections (specimens that have been professionally prepared by the laboratory staff). These students perform all aspects of dissection including skin removal, fat and fascia removal, and muscle reflection. Each group is also responsible for the self-delegation of laboratory duties among its members throughout the entire dissection. For instance, some group members dissect while others study from the bones, professionally dissected specimens, and other available resources to learn the related anatomical concepts before returning to their station to teach the dissectors what they learned. The PRO groups use the same laboratory resources; however, they do not perform any dissection tasks. In contrast, the PRO students use the dissections performed by their peers to explore anatomical structures and conceptualize their relationships. In this way,
PRO students view partially completed dissections from week-to-week as the course progresses, and sometimes witness their peers performing dissections in the additional open-laboratory hours. This provides PRO students with an ‘enhanced’ anatomy laboratory experience in comparison to traditional PRO approaches (see Section 1.2.2 and Chapter 3).

Students in the course are required to learn a large amount of anatomy and maintain a high level of detail in their understanding. To accomplish this, they are expected to use the full potential of the laboratory and its resources. A novel CAL resource was created to supplement both the DI and PRO environments in this course. The resource was divided into several units that covered important structures and concepts related to the content covered in the fall semester (regions of the back, upper limb, thorax, and abdomen). The goal was to highlight areas of the body that were difficult to perform for novice student disectors (especially under the existing limitations to their weekly laboratory time) and help to illustrate important anatomical structures and relationships associated with each region (see Section 4.2.3.2).

4.2.3 Theoretical Design Considerations

4.2.3.1 Defining ‘Concepts’ in Human Anatomy Education

Human anatomy is often considered a field in which learning is accomplished primarily by rote memorization of the names and features of various structures. However, these individual structures can often be united within a larger organizational framework. In this thesis, unifying themes that generalize relationships between the constituent parts of a region or system in human anatomy are termed ‘concepts’. Concepts can be used to
help students form ‘mental maps’ of the content by chunking the information into manageable groups of related information (Gobet et al., 2001). For example, letters can be ‘chunked’ into words, which can be further chunked into paragraphs that have unified governing themes (Simon, 1974). In this example, if a student understands the general theme of the paragraph, the words and letters that constitute those words become second-nature (Gobet et al., 2001). This conceptual approach to teaching may help to guide human anatomy students toward a comprehensive understanding of the body, rather than a disconnected surface understanding of its structures.

In anatomy, a concept could include themes such as the organizational characteristics and relationships between structures and their pathways, the symbiosis of structure and function among anatomical units, or the developmental trends and similarities that group these units together. For example, following the suprascapular nerve and artery as they travel from the supraclavicular region toward the supraspinatus and infraspinatus muscles can highlight important pathways and relationships in the shoulder region along the way:

The suprascapular nerve travels posteriorly through the suprascapular notch, which is bridged by the suprascapular ligament. The suprascapular artery travels superior to this ligament where it then rejoins the suprascapular nerve and together they supply the supraspinatus muscle. As a neurovascular bundle, the suprascapular nerve, artery, and vein then course through the spinoglenoid notch to ultimately supply the infraspinatus muscle.
Several important concepts can be highlighted by the teacher in the above example. In addition to providing an overview of the general organizational framework for the region (including bones, landmarks, muscles, ligaments, etc.), the complex relationship between the suprascapular nerve and artery can also be used to solidify an understanding of how neurovascular components often share common pathways as they travel in neurovascular bundles. The students can use this new understanding of neurovascular bundles as a formula when they encounter similar branching patterns in different regions of the body.

Another meaningful concept encountered all throughout the body is the relationship between structure and function. For example, analyzing the actions of the biceps brachii muscle can be used to demonstrate various concepts of locomotion:

The tendinous attachments of the biceps brachii muscle cross both the shoulder joint (the long head of biceps brachii originates on the supraglenoid tubercle of the scapula, the short head of biceps brachii originates on the coracoid process of the scapula) and the elbow joint (the biceps brachii muscle inserts on the radial tuberosity). Therefore, it can produce flexion at both the shoulder and the elbow as it contracts along the direction of its fibers. Because of its attachment on the radial tuberosity, it can also assist in supination of the forearm.

The basic concepts of muscle contraction and movement addressed in this example represent simple conceptual principles that apply to every muscle in the body. This
example can also be expanded to address concepts like relative movement and optimal muscle contraction length through a demonstration of radial tuberosity displacement during pronation and how that can result in lengthening of the biceps brachii muscle, bringing it out of its optimal contraction length and leading to less force production during elbow flexion compared to when the forearm is in a supinated position.

Finally, although embryology is often considered a subject of its own, embryological development can be used to shed new understanding on adult gross anatomy. For example, describing the growth and torsion experienced by the gut tube during embryonic development can be used to bring clarity to the complex blood supply of the foregut, midgut, and hindgut. Adult abdominal blood supply can, at first, look disorganized and visually complex; however, a basic understanding of embryological development can simplify this system for the students:

The gastrointestinal system begins as a relatively straight tube divided into three sections: the foregut, the midgut, and the hindgut. Three major arteries arise from the abdominal aorta to mirror this organization; branches from the celiac trunk (CT) supply the foregut, branches from the superior mesenteric artery (SMA) supply the midgut, and branches from the inferior mesenteric artery (IMA) supply the hindgut. During development the gut tube experiences a large amount of growth and associated torsion. When this process is complete, the organs become situated in the final and familiar positions typically observed in adults. Throughout embryological development and into adulthood, the organization of blood flow described
above is maintained, resulting in a continuation of the original relationships between the foregut and CT, midgut and SMA, as well as the hindgut and IMA.

A basic understanding of this concept can allow the students to use blood supply from the abdominal aorta as a roadmap to the abdominal organs or vice versa. Similar forays into embryological development can also be used to facilitate students’ understanding of structures like the heart or the relationships between the kidneys, ureters, and bladder.

The above are examples of how teaching more than simply the names and locations of structures can unveil deeper connections between the structures that can usually be applied to many other regions of the body. This approach allows the students to simplify their learning by introducing an underlying concept that helps to reduce the volume of subject matter that requires rote memorization. Instead, they are taught a formula that can include many structures and can be applied to various bodily regions. Targeting educational outcomes toward larger conceptual frameworks and encouraging students to consider the abstract connections between different structures may therefore be used to promote more meaningful learning and support better knowledge recall (see Section 1.3) (Bloom, 1956; Biggs, 1987; Gobet et al., 2001; Newton and Martin, 2013).

4.2.3.2 Selection of Concepts and Descriptions of Resource Content

In human anatomy, there exists a seemingly endless range of possible organizational concepts that can be targeted in every region of the body. However, since CAL resource created for this thesis was specifically targeted to the first semester of the
human anatomy course at UG, the content was limited to the back, upper limb, thorax, and abdomen regions. In consultation with the course instructor (Dr. Lorraine Jadeski), a list of potential themes and concepts was compiled for each unit. Dr. Jadeski has over 15 years of teaching experience in human anatomy at UG which she used to identify concepts that are integral to the course but can be difficult to observe on student-performed dissections in each unit. One anatomical concept from each unit was ultimately chosen to be included within the CAL resource, providing a cadaver-based adjunct that bridged lecture and laboratory content. The following section will describe the concepts and content highlighted in each unit of the resource.

**Back Unit (Appendices A and B)**

For the back region, the concept that was identified for inclusion in the CAL resource was the segmental nature of the vertebral column and branching of spinal nerve components toward their peripheral target regions. Ultimately, the goal for the CAL resource in this unit was to convey an understanding of the afferent and efferent systems that communicate with the spinal cord at each spinal segment, and how they are organized within the different components of a spinal nerve. These concepts were established early in this unit, then applied in clinical contexts throughout the entire course. In the back unit itself, students are often asked to assess hypothetical injuries to specific components of a spinal nerve (rootlets, roots, spinal nerve, rami) and comment on the associated loss of motor and sensory function. However, in later units, the students may be asked to evaluate a hypothetical injury to the spinal cord and comment on the functional impairments associated with the motor and sensory system in that scenario. In
this way, basic concepts associated with the function of the peripheral nervous system are established early in the course and applied throughout.

As the first region that is covered in the course, the back unit must also be used to address more fundamental concepts of human anatomy such as orientation and proper anatomical terminology. Thus, before embarking on learning the more complex concepts, the students must first be oriented to the more basic content of the region. Accordingly, the back unit of the CAL resource first covered the osteology of a typical vertebra and the structure of vertebral column. It especially highlighted the vertebral foramen, which houses the spinal cord, as well as the osteological processes (vertebral body, pedicles, superior and inferior articular processes) and intervertebral discs that form the intervertebral foramina through which the spinal nerves travel to exit the vertebral column. This content was then applied using a clinical scenario in which an intervertebral disc herniation into the intervertebral foramen was used to highlight a spinal nerve impingement. The content that followed built upon these concepts by discussing the segmental branching of rootlets from the spinal cord, the convergence and divergence of the different nerve components along their pathway into the periphery, and the distribution of afferent and efferent nerve fibres in each segment of the spinal nerve. For this, the students had to be first oriented to an image of a laminectomy which is the most common way they see the spinal cord in the cadaver laboratory at UG. This orientation was taught by describing the structures of the vertebrae that were required to be cut to perform a laminectomy and using cadaveric images and video animations to illustrate the process. The rootlets, roots, spinal nerve, and rami were then explained using schematics and
detailed images of cadaver dissections, with colourful video animations depicting the distributions and directions of afferent and efferent nerve fibres in each component. Finally, hypothetical injuries to the spinal cord and various spinal nerve components were used to reiterate the flow of motor and sensory signals and subsequent functional implications resulting from each injury. As these fundamental concepts of nerve formation and nerve signaling are among the first topics that students cover in the course, they serve as the basic scaffolding that is built upon in the units that follow.

*Upper Limb Unit (Appendices C and D)*

Continuing with the nervous system-centered theme, the content covered in the CAL resource for the upper limb focused on the mixing of anterior rami (derived from the segmentally-branching spinal nerves) within the brachial plexus. In this unit, the students are faced with what is at first an overwhelming number of structure names, functions, and relationships. Accordingly, the anatomical content for this unit was organized under the conceptual umbrella of function and spatial organization by grouping brachial plexus-derived structures based on the peripheral regions that they innervate. This is the first unit in which students encounter a nerve plexus and begin to associate multiple body systems together using function and common spatial relationships and pathways between structures. Therefore, the upper limb unit is used as an opportunity to familiarize the students with these concepts and help them to develop a framework that they can apply in different regions of the body.

The presentation of upper limb content in the CAL resource began by orienting the students to the axillary region through the identification of important osteological
landmarks such as the relevant cervical (C) and thoracic (T) vertebrae, first rib, clavicle, scapula, and humerus. It then demonstrated the basic structure and pathway of the brachial plexus using an animated walk-through of its components (roots, trunks, divisions, cords, and branches), followed by a demonstration on cadaveric images highlighting the important structures. Special emphasis was given to the contributions from each anterior ramus (C5, C6, C7, C8, and T1) found in the various downstream components. The resource went on to elaborate upon these basic principles by focusing on the medial, lateral, and posterior cords of the brachial plexus and the branches that they give rise to. Using coloured animations, the students were shown the contributions from each anterior ramus that comprised the cords and their subsequent branches. They then followed these nerve branches into their peripheral target regions to identify the muscles that they innervate, and the different regions of cutaneous innervation associated with each cord. Once again, a hypothetical spinal cord injury was used as an application of the anatomy learned throughout the unit. An injury to the lower cervical spine was depicted and the students were coached through the subsequent signaling deficiencies associated with each component of the brachial plexus as a result of the injury, focusing on the loss of muscle function from damaged branches. Addressing these concepts early in the course was an attempt to lay the groundwork that would allow students to quickly familiarize themselves with similar structures and relationships in later units, such as the lumbar and sacral plexuses and their downstream components.
Thorax Unit (Appendices E and F)

The thorax region is the first unit that is covered in the course after the midterm examination. In a sense, this is a transitional point in the course wherein the content shifts from having a large focus on the nervous and musculoskeletal systems to concentrate more on the cardiovascular system and the vital organs found within the body cavities. Accordingly, the flow of blood through the arterial system is used as a ‘road map’ to organize the structures and their relationships within the body. Therefore, the CAL resource unit for the thorax region focused on the flow of blood through the heart and into the coronary vessels that supply blood to the heart. By following the journey of deoxygenated blood that becomes re-oxygenated by the lungs and returned through the periphery, this unit sought to impart a three-dimensional (3-D) understanding of the heart, its function, and its location within the thorax.

To orient the students, the CAL resource began the unit with an overview of the osteology of the thoracic cage and a description of the position of the heart within the thorax. Video animations and cadaveric images were then used to follow the pathway of deoxygenated blood returning to the heart via the superior and inferior vena cavae. The animations then depicted blood flow through the right side of the heart, drawing the students’ attention to the chambers, valves, and other important structures found within the heart such as the pectinate muscles, chordae tendineae, papillary muscles, trabeculae carneae, and the septomarginal trabecula. After acknowledging the reoxygenation of blood in the lungs and its associated route through the pulmonary vessels, the left side of the heart was highlighted in the same fashion as the right. Finally,
the blood was followed out of the heart on its way to the periphery via the aorta. The unit was continued through an exploration of the first two branches off the ascending aorta, the left and right coronary arteries, and their role in blood supply to the walls of the heart. Specific relationships between the coronary arteries and cardiac veins were highlighted in relation to the areas of the heart on which they can be found. To conclude the unit, a clinical application was used to solidify an understanding of spatial relationships within the thorax. For this application, the example of a myocardial infarction caused by a blockage in the anterior interventricular artery was introduced and students were walked through the basic anatomy associated with a coronary artery bypass graft using the internal thoracic artery (ITA). Special attention was given to the relative positions of the heart, coronary vessels, and ITAs to highlight their proximity and help students to establish a 3-D understanding of the region. The traditional role of the ITA was discussed and students were prompted to consider the possible ramifications that this surgery may have on blood flow to the diaphragm. This opened the opportunity to discuss the redundancies in diaphragmatic blood flow from the phrenic arteries that branch from the descending thoracic aorta and their potential to compensate for the loss of an ITA. This type of application prompts students to both consider the 3-D nature of human body and the concept of arterial redundancies for the maintenance of blood flow. These concepts are previously encountered by the students during the upper limb unit (e.g., the anastomoses of collateral and recurrent arteries around joints) and are revisited in the abdomen unit (discussed below). Accordingly, understanding these concepts can allow
students to focus on the function of these components and higher-level applications of their knowledge.

*Abdomen Unit (Appendices G and H)*

The abdomen is the final unit covered in the fall semester of the course. For this unit, the CAL resource continued to focus on overarching concepts related to the organization of structures and their relationships to one another. Specifically, the resource explored the embryological development of the gut to highlight the relative positions of the abdominal viscera and the organization of the arteries that supply each organ. At first, the adult abdominal cavity is a very visually complex region that is typically difficult for students to understand. By explaining the embryological origins of the gut components that are maintained throughout development and into adulthood, the CAL resource aimed to give students the ability to organize their approach to understanding the visceral and arterial components of the region in the laboratory.

The CAL resource first highlighted the basic osteology, landmarks, and muscular borders of the abdominal cavity to introduce an awareness of the important landmarks that are traditionally used as spatial references. Animated schematics were then used to illustrate the reorganization of the viscera and associated blood vessels during embryological growth and development. This was intended to give students a visual representation of how the gut transitions from a relatively simple system to the complicated network of structures they typically encounter within the adult cadavers in the laboratory. This illustration was followed by a breakdown of the final position of each organ in the adult abdominal cavity. The resource then went on to explore the abdominal
 arteries in greater detail. Beginning at the descending abdominal aorta, the students used the computer mouse to click through animations that highlighted each artery toward the organs that they supply with oxygenated blood. This section of the resource was organized based on the major blood vessels (CT, SMA, IMA) that branch directly from the abdominal aorta, following each artery that they give rise to. Special attention was given to the anastomoses between arteries that connected blood flow between the foregut and midgut (superior and inferior anterior and posterior pancreaticoduodenal arteries) as well as between the midgut and hindgut (middle and left colic arteries). These two communication sites were also used to highlight the abdominal viscera that are associated with each embryological gut region and identify the points of transition between foregut-, midgut-, and hindgut-derived structures. To emphasize this connectivity, a clinical application was used to explore a hypothetical blockage in the left colic artery that disrupted blood supply to the distal third of the transverse colon and the descending colon. Coloured animations were used to demonstrate how the blood supply can be restored and maintained through anastomoses that exist between the left colic artery and middle colic artery (from the SMA), as well as between the left colic artery and the sigmoidal branches (from the IMA). This emphasis on arterial anastomoses echoed the concepts addressed in the thorax unit and prepared the students for future study of anastomoses in the second semester of the course (such as those around the knee joint and brain). In addition, providing the students with a basic knowledge embryological development gives them an organizational framework that they can apply to anatomical structures and relationships in the adult.
4.2.3.3 Cognitive Load and Multimedia Design

Designing an effective multimedia resource requires careful attention to the underlying cognitive processes involved in learning from words and pictures. This notion is encompassed by the cognitive theory of multimedia learning (CTML), which is a derivative of cognitive load theory (CLT) (DiGiacinto, 2007; Levinson, 2010). These two theories assert that incoming information is processed by the brain through two distinct channels – the visual or pictorial channel and the auditory or verbal channel (Sweller et al., 1998). During learning, the sensory memory is subjected to a flood of incoming stimuli from the environment; however, it can only select and process a certain amount of information through each channel at one time (Sweller, 1988; Sweller et al., 1998). The information that is ultimately selected by the sensory memory is next transmitted to the working memory where it is encoded as distinct cognitive representations, which are subsequently integrated with relevant prior knowledge and sent to long-term memory for storage (Mayer et al., 2001). The part of this process that is of particular importance to CLT and CTML is the notion of limited capacity for information processing, or the 'load', through each channel of the sensory memory (DiGiacinto, 2007; Levinson, 2010; Issa et al., 2011). These theories suggest that if even one of the channels is overloaded by extraneous stimuli, the learner's capacity to create accurate and comprehensive cognitive representations of the important information can be compromised (DiGiacinto, 2007; Levinson, 2010). Ultimately, this cognitive overload can lead to reduced understanding of the target material and impairments to academic performance (Sweller et al., 1998; Lahtinen et al., 2007; DeLeeuw and Mayer, 2008).
Cognitive overload is thought to originate from pressures to three distinct types of cognitive demands: essential processing, incidental processing, and representational holding (Mayer and Moreno, 2003). Essential processing relates to cognitive tasks that are required to understand the important information presented in a learning activity (Mayer and Moreno, 2003). Conversely, incidental processing involves the cognitive processes that are devoted to ‘distractors’, or non-essential information, introduced by the format of the learning task (Mayer and Moreno, 2003). Finally, representational holding refers to the cognitive process of maintaining a mental representation of the important information in the working memory for a length of time, such as between two pages of a book or two presentation slides (Mayer and Moreno, 2003). During multimedia learning, each of these cognitive processes are required in both the verbal and pictorial channels as the learner attempts to interpret the incoming combinations of pictures, videos, text, and audio cues.

Since human anatomy is an information-dense subject that includes a large amount of target material, it was important to ensure that the CAL resource created for this thesis was carefully designed to present the important information with minimal opportunities for cognitive overload in the verbal and pictorial channels. Several multimedia design principles were therefore used to balance the task-load between the two channels and maximize the efficiency of content presentation in the CAL resource, thereby reducing essential processing, incidental processing, and representational holding demands (Mayer and Moreno, 2003). Overall, resources that adhere to such principles of multimedia design have been suggested to promote greater reliance upon
DAs to learning and improve knowledge retention (Mayer, 2001; Issa et al., 2011). Since pictures, animations, and accompanying text descriptions were used to present all of the relevant information in the CAL resource, the resource relied heavily on the visual channel. This presented the risk of cognitive overload from essential processing demands in that channel (Mayer and Moreno, 2003). Normally in this situation the strategy of 'off-loading' is used, wherein the text-based information is instead presented as audio to evenly distribute the cognitive demand between the learner's eyes and ears (Mayer and Moreno, 2003). However, due to the high noise-levels associated with group learning in the laboratory environment, audio could not be included as a feature of the CAL resource. This meant that design strategies such as 'segmenting' and 'pretraining' had to be used more liberally to limit cognitive load (Mayer and Moreno, 2003). Segmenting is the practice of breaking-up the information into easy-to-process units that allows the learner to encode the information as separate chunks that together encompass the entire topic (Gobet et al., 2001; Mayer and Moreno, 2003). Similarly, pretraining involves teaching the basic content before incrementally building towards more complicated and cognitively demanding material (Mayer and Moreno, 2003). These two approaches were therefore used together to scaffold the content and reduce cognitive load presented by the CAL resource (Mayer and Moreno, 2003; van Merriënboer and Sweller, 2005; Kalyuga, 2007). Another consideration in the development of the resource was the limitation of non-essential information that can place undue strain on the learner's capacity for incidental processing (Mayer and Moreno, 2003). To mitigate these factors and attenuate cognitive overload, the principles of 'weeding' and 'signaling' were used (Mayer and Moreno, 2003).
Weeding involves the elimination of information that is not essential to understanding the primary concept at hand, including extraneous pictures or animations (Mayer and Moreno, 2003). If the distracting information cannot be removed, one may instead 'signal' the important information to the learner to help them identify and select the crucial data from which to form cognitive representations (Mayer and Moreno, 2003). Accordingly, substantial efforts were made to ensure that minimal superfluous images and non-essential data were included in the CAL resource and the important information was highlighted using colours to emphasize relevant text and areas of images as necessary (see more detailed design information in Section 4.2.4). Finally, the content was presented in a clear and concise manner to help the students form organized cognitive representations of the information, which promotes stronger long-term knowledge retention (Mayer and Moreno, 2003; Biggs and Tang, 2011; Unsworth, 2016). Namely, proper 'synchronization' of the text, images, and necessary animations was maintained to reduce overload from excessive incidental processing and representational holding demands that are associated with fragmented content presentation (Mayer and Moreno, 2003). Using these and the other strategies discussed in this chapter, the resource was intended to integrate into the course as a study tool that contributed to the students' successful completion of the intended learning outcomes.

4.2.3.4 Alignment

The way in which a novel resource is integrated into a course also merits considerable attention. These resources should be designed to specifically address the criteria stated in the course learning objectives, guide students toward successful
achievement of the intended learning outcomes, and allow them to qualitatively assess whether they have accomplished those outcomes (Cohen, 1987; Biggs, 1996; Biggs and Tang, 2011). This idea is foundational to the theories of instructional and constructive alignment (Cohen, 1987; Biggs, 1996; Biggs and Tang, 2011). These theories propose that alignment is essential at all levels of educational design including the program-level, the course-level, and even at the level of individual learning resources (Cohen, 1987; Biggs, 1996; Biggs and Tang, 2011). Furthermore, each of these levels work in concert to deliver a transformative learning experience (Cohen, 1987; Biggs, 1996; Biggs and Tang, 2011). For instance, a medical education program may have the general goal of creating competent doctors who are leaders in healthcare. The administrators of such a program would subsequently tasked with defining specific traits that characterize the ideal doctor and determining the required courses that would foster those traits in their students. The course instructors would then be required to ensure that what they teach would actually help students to successfully develop those traits. For this, alignment theories suggest that they communicate the learning goals to the students, expose them to learning activities that address the stated goals, and directly evaluate their success at completing those goals (Cohen, 1987; Biggs, 1996; Biggs and Tang, 2011). Similarly, the learning activity itself must be designed with the overall course and program goals in mind to ensure that the content is aligned with the overall intended learning outcomes (Cohen, 1987; Biggs, 1996; Biggs and Tang, 2011). This type of alignment has been associated with deeper approaches to learning in various subjects, including human anatomy (Wang et al., 2013).
Given the suggested benefits that alignment practices can have on SAL (Biggs and Tang, 2011; Wang et al., 2013), special attention was placed on how content was organized within the CAL resource and how it was integrated into the course. Namely, as outlined in Section 4.2.3.2, the CAL resource included four separate units that aligned with the four main regions discussed in the course. This meant that the content and the depth with which it was covered in the resource was based upon the learning outcomes that were presented to the students in the course outline. Moreover, the CAL resource was designed to have as much internal alignment as possible. For instance, each unit of the resource had a set of intended learning outcomes that were communicated to the students at the beginning of each section. After reading these objectives, the students navigated through the relevant content until they reached the end of the section where they re-encountered the intended learning outcomes alongside summaries of the specific content that addressed each one (see Section 4.2.4.2 for a more detailed description of the CAL resource organization). Through this organization, students were able to have a clear understanding of what was expected of them for each unit of the CAL resource, pursue learning activities that directly targeted those goals, and self-evaluate their success at achieving those goals.

The intended learning outcomes for each section of the CAL resource were designed to scaffold from low to high levels of cognitive difficulty using principles from Bloom’s Taxonomy of Educational Objectives (BT) (Bloom, 1956; Anderson et al., 2001). BT is a theoretical framework that is commonly used to classify the cognitive level of learning activities and communicate learning goals to the learner (Bloom, 1956;
Krathwohl, 2002). The most recent version of BT includes six levels that use active verbs to depict what the student should be able to do at each level of cognitive processing: remember, understand, apply, analyze, evaluate, and create (Anderson et al., 2001). Using active verbs such as “explain”, “apply”, or “draw” results in learning outcomes with measurable goals that the students can use to evaluate their own learning success, while non-measurable terms such as “understand” or “learn” are typically avoided because they are vague and difficult to evaluate (Anderson et al., 2001). This updated version of BT has been subsequently adapted to fit various specific disciplines, including anatomy (Crowe et al., 2008; Thompson and O’Loughlin, 2015). The Blooming Anatomy Tool (BAT) includes discipline-specific outlines of the characteristics that must be demonstrated and the subsequent skills (action verbs) that are assessed at each of the first four levels of BT (Anderson et al., 2001; Thompson and O’Loughlin, 2015). The BAT was therefore used in the creation of the CAL resource for its specificity to anatomy curricula (Thompson and O’Loughlin, 2015). Ultimately, this tool offered a framework for creating and communicating intended learning outcomes that aligned the content presented in the CAL resource with the specific goals of each unit and the broader objectives of the course (Biggs, 1996; Biggs and Tang, 2011; Thompson and O’Loughlin, 2015).

4.2.4 Technical Design Considerations

4.2.4.1 Dissection, Image Capture, and Photo-editing

After the anatomical concepts were chosen and a theoretical framework for the creation of the CAL resource was agreed upon, each dissection was planned by the
author with guidance from Dr. Lorraine Jadeski. Before beginning each dissection, a ‘story-board’ was created to depict the relevant structures and viewing angles for each phase of the CAL resource. These plans were sure to encompass all of the relevant anatomical structures and how their depth and relationships could be most clearly depicted.

Dissection

Two cadavers were used in the creation of the back unit, one for the upper limb unit, and one cadaver was used for both the thorax and abdomen units. All dissections were performed by the author between January 2015 and November 2016. Each dissection began with the removal of skin with careful attention to the borders of each region. Relevant structures were then carefully uncovered from the surrounding fat and layers of connective tissue to reveal their pathways and relationships to one another. The dissections were then continued to reveal deeper structures by reflecting or removing muscles and other more superficial structures after the necessary photographs were taken. This process continued until all the required photographs were collected for each unit. In addition, authentic human bones and models of human skeletons from Bone Clones were photographed to demonstrate the osteology of each region. The use and imaging of cadavers for the creation of the CAL resource was executed according to the Human Anatomy Program Code of Conduct, with permissions from Dr. Lorraine Jadeski and the manager of the human anatomy laboratory, Premila Sathasivam.
During the photography of the dissected specimens, careful attention was placed on proper anatomical positioning of structures. Given that the CAL resource’s intended use was to supplement an introductory anatomy course, the ‘normal’ relationships between structures were highlighted whenever possible; however, encountering anatomical variability is an inevitability when using human cadavers (Tubbs et al., 2016), so when variations from traditional anatomy were encountered, they were photographed and used as opportunities to highlight this concept. For all photography, a Canon EOS 5D Mark II digital single-lens reflex (DSLR) camera was used. This camera was mounted to a custom-built stainless-steel stand that allowed for over-table image capture. The stand had rails that allowed for 3-D movement of the camera, including a ball-in-socket component for angled shots. A Canon EF 40mm f/2.8 STM macro lens was used for full-length photographs and a Canon EF 50mm f/2.5 compact-macro lens was used for close-range shots. The camera was wired directly to an iMac desktop computer running Mac OS X that was used to control the DSLR camera’s manual functions through the image capture program, Canon EOS Utility. Using this program allowed for manual adjustment of settings such as zoom and focus for each photograph without touching the camera and inadvertently altering its position and subsequent alignment with the specimen.

To obtain the highest possible image quality, a focus-stacking (FS) image capture technique was used. FS is an imaging technique that artificially enhances the depth of field (DOF) in an image (Skrzat, 2011). The FS technique is commonly used in microscopy whereby image processing software is used to fuse multiple digital images
with different focal planes to create a single image with an extended DOF (Kerp and Bomfleur, 2011; Skrzat, 2011). A pilot study conducted for this thesis showed that students generally rated FS images higher in quality than non-FS images, especially those depicting specimens with demonstrable depth (McWatt and Jadeski, 2017). These findings supported the use of FS in the capture of educational anatomical images for this thesis. To perform FS for the CAL resource, multiple images with a narrow DOF were taken of each specimen. The first image in each series was focused on the area of the specimen closest to the camera, then subsequent images were taken with the focus set to incrementally increasing distances from the camera lens. Using the photo-editing program, Adobe Photoshop CS6, a z-stacking algorithm was applied to align and merge all of the images in the series, resulting in a single image with sharp focus across the entire depth of the specimen. These high-quality images allowed small and detailed structures to be clearly depicted within the CAL resource.

**Photo-editing**

Adobe Photoshop CS6 was also used to prepare the raw images for inclusion in the final CAL resource. These edits included cropping the images, removing their backgrounds, and creating coloured layers that highlighted structures of interest. Specifically, the highlights comprised of semi-transparent layers to highlight relevant structures without obscuring their detailed textures. Occasionally, gradient effects were also used to focus the students’ attention on important areas of the dissection by hiding distracting and non-essential structures that could not be removed or cropped from the pictures. These are examples of how signaling and weeding were used to limit cognitive
load (Mayer and Moreno, 2003). Photoshop was again used to create accurate anatomical schematics, allowing the students to encounter simplified content before moving on to more complicated cadaveric images. To create the schematics, various filters and colour reductions were applied to cadaveric images to make them appear as if they were hand-drawn. These simplified schematics opened an opportunity for clearer depictions of structures and their relationships, as well as animated demonstrations of functions or processes in which the structures were involved. This exemplifies the use of pretraining to reduce cognitive processing demands (Mayer and Moreno, 2003).

4.2.4.2 Organization and Presentation of Content

The CAL resource was segmented into four units (back, upper limb, thorax, and abdomen), each comprised of two sections (see Appendices A – H). The purpose of dividing the units into smaller sections was a twofold attempt to reduce cognitive load through segmenting and pretraining (Mayer and Moreno, 2003). For instance, each unit began with a section that covered the osteology and basic anatomy of the region, including any relevant landmarking structures required for orientation. The second section then expanded upon this content to build a comprehensive view of the region, tied together using one overarching concept (see Section 4.2.3.2). This segmented the content into smaller stepwise components and allowed students to grow more comfortable with the basic content before moving on to more complex cognitive tasks.

Further attempts to limit cognitive load were applied through the organization of each specific section of the CAL resource. Primarily, all eight sections followed the same general format that was aligned using BT-based intended learning outcomes:
1. Section Overview and Review of Terminology
   • Each section began by describing the content that would be encountered, introducing important terminology, and describing how the content integrated into the overarching anatomical concept covered in that unit of the CAL resource.
   • In the second section of each unit, a hyperlink directing the students to a review of the content that was covered in the first section was also included (see Appendices B, D, F, and H).

2. Intended Learning Outcomes
   • Three learning outcomes of progressively increasing BT levels (see Section 4.2.3.4) were included in each section.

3. Anatomical Content
   • After the intended learning outcomes were introduced, the students encountered a walk-through of the important anatomical structures and their relationships with synchronized coloured image highlights and text descriptions.

4. Applications
   • Each section concluded with a clinical scenario that was used as a perturbation to the normal structures, relationships, or functions, encouraging the students to review and apply the anatomy learned throughout the section in a new context.
5. Review

- At the end of the section, each of the initial intended learning outcomes was re-introduced alongside a brief review of the content that had addressed that outcome.
- Hyperlinks to the related content within the module were also provided to allow students to return to the content if they felt their knowledge was insufficient.

By maintaining the same format and organization, the students could become more familiar with the style of presentation in the CAL resource throughout the semester. This can act to mitigate some of the cognitive load from incidental processing that would be associated with navigating a foreign resource in each unit (Mayer and Moreno, 2003).

An additional factor that made the CAL resource more familiar to the students was that it was built using Microsoft PowerPoint. PowerPoint is widely used in higher education as a multimedia tool to deliver lectures and presentations (Issa et al., 2011). Many instructors also upload their PowerPoint lectures onto their course website to allow students to make annotations and study the lectures from home. This means that the students are highly familiar with using and learning from PowerPoint-style resources. Furthermore, PowerPoint has various functions such as animations and shapes that can be customized to communicate complicated processes and emphasize important information. Accordingly, animations were used to synchronize the introduction of coloured highlights on the cadaveric images with text descriptions of the highlighted
structures. The font colour of the text descriptions also matched the colour of the highlights on the image. By signaling the important content and synchronizing it with relevant descriptions in this manner, cognitive demands associated with incidental processing and representational holding were mitigated (Mayer and Moreno, 2003). Given these benefits to cognitive load associated with using PowerPoint, it offered an ideal medium for the creation and the dissemination of the CAL resource.

4.2.4.3 Resource Accessibility and Dissemination

The final versions of the different sections of the CAL resource were saved as PowerPoint Shows (see Appendices A – H). This format disabled the editing capabilities of the program, while maintaining the format and interactivity of a typical PowerPoint presentation. Because of concerns surrounding the privacy of the body donors and the risk of online content sharing, the resource was only made locally available to the students via an offline website hosted on each of the eight laboratory computers (Lenovo ThinkCentre M800 with Intel Core i5 processors, running Windows 10 Pro). PowerPoint Viewer was used to display the content on monitors (BenQ GW2870H) that were mounted on multiple-jointed arms to allow the students to easily adjust the monitor height and angle to the position they felt offered optimal viewing. Since there was one computer for each laboratory group, the students shared the station with six or seven of their groupmates. Access to the CAL resource was permitted whenever the laboratory was open, including in the weekly extra open-laboratory hours.

Students navigated the resource by using the mouse to click or scroll through the content. With each click, some combination of images, highlights, illustrative animations,
and text was revealed to incrementally guide the students through the relevant anatomical structures and relationships required to understand the concept. For instance, if a short paragraph of descriptive text had appeared after one click, the name of an important anatomical structure would be displayed in a coloured font to highlight its importance. Accordingly, that anatomical structure would have been simultaneously highlighted in the same colour on the corresponding image. Once the student was satisfied with their understanding of the content, they were able to click or scroll to advance to the next point. Conversely, the students were free to return to previous points using the scroll-wheel on the mouse. In this way, the students were directed through the content in a specific order, while maintaining their own control over the pace of their learning. Features of self-directed learning activities such as this have been associated with increased use of DAs to learning (Reeves et al., 2004; Findlater et al., 2012; Brophy, 2013).

4.2.5 Conclusion

To supplement the existing DI and PRO laboratory environments of a third-year undergraduate human anatomy course at UG, a curriculum-targeted CAL resource was created. This resource integrated images of cadaver dissections and descriptive text using various multimedia to yield an interactive and student-paced learning tool. Careful attention was also given to alignment and multimedia design principles to minimize cognitive load and promote meaningful learning behaviours. This resource was introduced into the course in the Fall 2016 semester during which time students’ use of the resource was monitored and evaluated for its influence on their satisfaction, SAL, and
academic performance (Section 4.3). Additional research was conducted to investigate
the role of the CAL resource in long-term knowledge recall (Chapter 5).
4.3 Context Matters: Assessing the Impact of a Curriculum-targeted Computer-assisted Learning Resource on Student Learning in the Human Anatomy Laboratory
4.3.1 Abstract

The methods for teaching anatomy are constantly adapting to overcome time and resource limitations and deliver powerful learning opportunities to students in the health sciences. One popular intervention includes the addition of computer-assisted learning (CAL) resources to supplement more traditional laboratory approaches. Accordingly, this study evaluated a novel CAL resource introduced into an undergraduate dissection- (DI) and prosection-based (PRO) human anatomy course at the University of Guelph between the Fall 2015 and 2016 semesters. The objective was to determine the influence of the resource on the students’ course satisfaction (CE), approaches to learning (SAL), and overall performance. Participants reported their demographic information, CE, SAL, and CAL resource use through a combination of online and written surveys. Written feedback was also collected and assessed by way of thematic analysis. Historical comparisons of CE, SAL, and performance were first made between the two academic cohorts. CAL resource use was then characterized in the DI and PRO environments and multiple linear regression analyses were used to determine its correlations with SAL and performance. Overall, the historical comparisons suggested that the course assumed a more surface-oriented environment in 2016 than in 2015, despite improvements in course satisfaction. SAL and performance were not directly influenced by CAL resource use; however, students who reported higher satisfaction with the resource adopted deeper approaches to learning. These findings, alongside the student feedback, illustrated that the context in which CAL resources are disseminated should be a primary consideration when incorporating such resources into a course.
Keywords: gross anatomy education; undergraduate education; student approaches to learning; student perceptions; deep and surface learning approaches; cadaver dissection; computer-assisted learning; computer-assisted instruction

4.3.2 Introduction

In the digitally-focused climate of current society, the use of computer-assisted learning (CAL) resources for teaching has become widespread in higher education. In human anatomy specifically, rapidly advancing digital imaging technology has allowed educators to tailor affordable visual resources to fit both their courses and the specific needs of their digitally-proficient millennial students (Prensky, 2001; Lancaster and Stillman, 2003; Wessels et al., 2015; Losco et al., 2017). Many have built and used these tools to compensate for reductions to their existing cadaver-based laboratories (Granger and Calleson, 2007; Johnson et al., 2012; Barbeau et al., 2013; Attardi and Rogers, 2015), while some have used CAL to replace dissection- (DI) and prosection-based (PRO) laboratories altogether (McLachlan et al., 2004; Wright, 2012). In most cases, however, institution-specific CAL resources have best served as supplements to traditional methods of anatomy instruction, providing students with individual study tools that align with the intended course learning outcomes (Adamczyk et al., 2009; McNulty et al., 2009; Losco et al., 2017).

Research surrounding the efficacy of using CAL resources in anatomy education is very context-dependent and has therefore unsurprisingly yielded mixed conclusions. Several studies have indicated that CAL resources, used either independently or in conjunction with traditional methods of learning anatomy, improved performance on
evaluations of knowledge in gross anatomy, physiology, and clinical competency (Qayumi et al., 2004; Glittenberg and Binder, 2006; Nicholson et al., 2006; Venkatiah, 2010; Pani et al., 2014). However, others have reported insignificant differences or even reduced performance on these knowledge-based outcomes among CAL users than those who used more traditional resources (Donnelly et al., 2009; Tam et al., 2010; Codd and Choudhury, 2011; Fritz et al., 2011; Hopkins et al., 2011; Saltarelli et al., 2014; Stirling and Brit, 2014).

One consistent finding in the literature regarding CAL use in anatomy education is that students generally report positive attitudes towards CAL resources, regardless of any quantifiable effect they may have on learning (Glittenberg and Binder, 2006; Venkatiah, 2010; Codd and Choudhury, 2011; Hopkins et al., 2011; Stirling and Brit, 2014). This overall positive perception of CAL offers educators a valuable opportunity to use CAL tools to communicate important course content. Millennial students in particular have been shown to value having the opportunity to customize their learning by choosing between the available learning approaches and resources (Pettit et al., 2017). Accordingly, if students view course-specific CAL resources as productive study tools, they may be more likely to use them for individual study rather than other publicly available resources that may mislead them and hinder their performance (Husmann and O’Loughlin, 2018).

When CAL resources are designed ‘in-house’, educators can curate the content and promote student learning activities that align with the specific course objectives (Biggs and Tang, 2011). Moreover, mindful creators can reduce cognitive load by
ensuring that external audiovisual distractors are minimal, related information is clustered into ‘mental frames’, and new content is integrated with the learner’s existing knowledge (Sweller, 1988; Sweller et al., 1998; Mayer and Moreno, 2003). When combined, these fundamental principles of constructive alignment and multimedia design offer a strong framework for creating CAL tools that are conducive to meaningful and efficient learning (Mayer, 2001; Mayer and Moreno, 2003; Biggs and Tang, 2011; Issa et al., 2011; Vogel-Walcutt et al., 2011; Wang et al., 2013). Furthermore, if students perceive this value, they may be more motivated to use the available CAL resources for self-directed study, which itself has been shown to promote meaningful learning (Reeves et al., 2004; Findlater et al., 2012; Brophy, 2013). Overall, encouraging self-directed study with course-aligned CAL resources has the potential to improve learning and standardize content delivery in a course.

4.3.2.1 Computer-assisted Learning at the University of Guelph

The University of Guelph (UG) offers a full-body cadaver-based human anatomy course in the third year of the Human Kinetics (HK), Biomedical Sciences (BIOM), and Biological Sciences (BIOS) undergraduate degree programs. The course uses DI and PRO laboratory environments to complement the traditional lecture. Although the course has benefited from continual institutional support, it nonetheless faces limitations to time and resources. Primarily, the time-intensive nature of learning anatomy has prompted the program to develop various teaching interventions that encourage self-directed learning and maximize the impact of the students’ time within the cadaver-based laboratory. One such development is a novel CAL resource that was introduced to broaden the range of
resources available for reference and self-directed learning within the laboratory (see Sections 4.2 and 4.3.3.3). This supplementary resource was available for the first time throughout the Fall 2016 semester in both the DI and PRO laboratories. It implemented cadaveric images and curriculum-aligned content that students could use for laboratory preparation, reference, and review. The students were able to learn the fundamental anatomical content and concepts using the CAL resource, leaving the limited contact time with the teaching assistants (TAs) and cadavers to focus on more complex dissection tasks and the pursuit of higher-order learning activities, including clinical applications and situational analyses (Anderson et al., 2001). Ultimately, this redistribution of the teaching load between the CAL resource and the TAs was intended to allow the laboratory sessions to run more efficiently while increasing the students’ opportunities to participate in meaningful learning activities and contributing to their success at learning anatomy.

4.3.2.2 Course Experience, Student Approaches to Learning, and Academic Performance

Although ‘success’ in higher education often encompasses more nuanced outcomes than simple grades, academic performance has remained the most widely used outcome to measure learning success (York et al., 2015). Holistically, outcomes of higher education range from the purely academic (acquisition of knowledge, attainment of learning outcomes, etc.) to more qualitative and elusive measurements of success (engagement, satisfaction, career success, etc.) (York et al., 2015). A popular method of promoting such higher-order outcomes is by using student-centered designs that focus on student approaches to learning (SAL) and encourage ‘deep’ rather than ‘surface’ interactions with the course material (Marton and Säljö, 1976; Weimer, 2013). While
surface approaches (SA) to learning generally involve strategies such as rote memorization that result in a superficial understanding of facts, deep approaches (DA) are characterized by more active attempts to obtain a comprehensive and nuanced understanding of a topic and promote skill development through high-level engagement (Marton and Säljö, 1976). Accordingly, changes in deep approaches are commonly used as a proxy measurement for meaningful learning (van Rossum and Schenk, 1984; Trigwell and Prosser, 1991; Newstead, 1992; Gibbs, 1994; Norton and Dickens, 1995; McCune and Entwistle, 2000; Zimitat and McAlpine, 2003; Wilson and Fowler, 2005; Pandey and Zimitat, 2007).

Since the initial research into SAL by Marton and Säljö (1976), measuring SAL in higher education has become a central component of describing how students learn. Specifically, the ‘3-P’ model proposed by Biggs (1987) explored the relationship between ‘presage’ factors and the ‘process’ of studying new information with respect to their combined influence on learning success, or the ‘product’. Presage factors include those that are present before learning is initiated, such as personal characteristics (age, sex, existing subject understanding, etc.) and situational elements (teaching approach, facilities, available resources, etc.) that are imposed by the learning environment (Biggs, 1987). These elements interact to influence SAL, a descriptor of the learning process, that will in turn influence the ultimate product (Biggs et al., 2001; Groves, 2005; Baeten et al., 2010; Wang et al., 2013; Rubin et al., 2016). Biggs further asserts that students possess a preferred SAL that they typically use as their default way of studying, and a contextual SAL that they use in reaction to a given learning environment (Biggs, 1987;
Biggs et al., 2001). Therefore, since contextual SAL is subject to influences from personal and situational factors, including the students’ own perception of the learning environment, it may differ from the preferred SAL (Biggs, 1987; Entwistle and Tait, 1990; Trigwell and Prosser, 1991; Lizzio et al., 2002; Wang et al., 2013). Consequently, differences between preferred and contextual SAs and DAs have been used to evaluate teaching interventions such as the introduction of novel resources or innovative techniques (Kember et al., 1997; Biggs et al., 2001; Rodriguez and Cano, 2007; Wang et al., 2013). Using this approach, the efficacy of CAL tools can be evaluated for their influence on the students’ course experience (CE), as well as their subsequent effects on SAL and course performance.

4.3.2.3 Aims and Hypotheses

Following the development of a novel CAL resource for use in undergraduate anatomy education in DI and PRO courses at UG (see Section 4.2 and Appendices A – H), the aim of the present study was to evaluate the effectiveness of the tool based on outcomes including: (1) student perceptions of the CE, (2) contextual SAL (including both SA and DA to learning), and (3) course performance. General comparisons of students’ CE, SAL, and performance were first made between the Fall 2016 and Fall 2015 DI and PRO cohorts. The F16 cohort was then examined independently to explore correlations between these outcomes and their use of the CAL resource. Written feedback from students was used to establish themes that described their perception of the impact of the CAL resource and the nuances of its implementation. It was expected that students would generally enjoy the CAL resource, leading to higher CE ratings and subsequently
higher contextual DA scores among Fall 2016 students than Fall 2015 students. The authors also hypothesized that Fall 2016 students who used the CAL resource more frequently would develop stronger foundational knowledge of anatomy, allowing them to pursue deeper approaches to learning in the laboratory. As a product of the learning process, academic performance was therefore expected to be better among students who had more frequent CAL resource use and higher contextual DA scores.

4.3.3 Materials and Methods

4.3.3.1 Subjects

The study participants were recruited from the third-year undergraduate human anatomy course at UG during the Fall semesters of 2015 and 2016. The course is compulsory for students enrolled in HK but is also available to students in BIOM (as a restricted elective) and BIOS (with signed instructor consent) in their third year of study. The first two years of the HK, BIOM, and BIOS degree programs share the same list of required courses except for various possible elective courses and a half-credit introductory biomechanics course offered in the second year of the HK major. In total, 306 students were enrolled in the human anatomy course in the Fall 2015 semester and 296 were enrolled in the Fall 2016 semester. For both years, all students attended the same lectures and completed the same assessments, but enrolled in either a DI (2015, n = 226; 2016, n = 235) or PRO (2015, n = 80; 2016, n = 61) laboratory cohort. All students were allowed to choose between DI and PRO when they registered into the course.

This study was approved by the UG Research Ethics Board prior to data collection and all participants indicated informed consent before completing the study protocol.
4.3.3.2 Course Description

This study focused on the first semester of a two-semester full-body human anatomy course (described in detail in Chapter 3). The course followed a regional approach, covering the back, upper limb, thorax, and abdomen regions in the first semester. During lecture, the students were taught fundamental anatomical structures and relationships through a combination of didactic teaching and drawing exercises. In the laboratory, students in both the DI and PRO cohorts worked in small groups to locate and observe structures on cadavers with guidance from their TAs. DI groups were assigned to half (right or left) of a full-body cadaver and performed all aspects of dissection throughout the semester, the PRO students then studied from those dissections during their laboratory sessions. This design exposed PRO students to partially completed dissections from week-to-week as the semester progressed, ‘enhancing’ the PRO experience (Chapter 3). Both cohorts also had access to laboratory textbooks, atlases, osteology, traditional prosections (professionally dissected specimens), and the new CAL resource that was made available on desktop computers in the laboratory. The course assessments included written tests (multiple choice and short answer questions), laboratory bell-ringer tests, and laboratory oral assessments (weekly competency quizzes and one small group oral presentation). Please see Table 3.1 in Chapter 3 for a detailed description of the general content and weight of each course assessment.
4.3.3.3 CAL Resource Design

The CAL resource was created in Microsoft PowerPoint using cadaveric images and accompanying text to convey major course concepts for the back, upper limb, thorax, and abdomen units. For each unit, dissections were performed and photographed to illustrate structures and relationships that the students did not have the time or expertise to dissect on their own body donors (theoretical and technical considerations outlined in Section 4.2). These concepts included, (1) the segmental nature of the spinal column, including the motor and sensory components of spinal nerves (back unit, Appendices A and B), (2) the organization and distribution of spinal nerve contributions within the brachial plexus and their peripheral innervation targets (upper limb unit, Appendices C and D), (3) the organization of and relationships between major thoracic structures and vasculature (thorax unit, Appendices E and F), and (4) the basic embryology of the arteries that supply the abdominal organs and their spatial organization (abdomen unit, Appendices G and H; see Section 4.2.3.2 for a detailed outline of the content included in each unit).

Each unit was split into two sections: (1) an introductory section that covered the relevant osteology and basic landmarks of each region, and (2) more detailed content and applications of the anatomy. The sections were organized to have internal alignment as well as alignment with the intended learning outcomes of the unit and overall course (Biggs and Tang, 2011). Each section began with a brief introduction of the concept and content to be discussed. The students were then presented with a set of intended learning outcomes for the section that used active verbs ranging from low (‘remember’ and
‘understand’) to high (‘apply’ and ‘analyze’) levels of Bloom’s taxonomy (BT). BT is a hierarchical framework that is commonly used to classify the cognitive level of learning activities, design learning outcomes, and organize the alignment of course elements to those outcomes (Bloom, 1956; Biggs and Tang, 2011). For this resource, the Blooming Anatomy Tool (BAT) was used (Thompson and O’Loughlin, 2015). The BAT is a specific adaptation of BT for use in anatomy that incorporates active learning verbs, as proposed in the revised version of BT (Anderson et al., 2001). Careful consideration was also given to multimedia design principles discussed in Mayer and Moreno (2003) for reducing cognitive load. Students were presented with a table of contents at the beginning of each section that allowed them to jump directly to content that they wished to see, and they were able to freely navigate through the tutorials using the scroll function on the computer mouse. The content itself was presented using the PowerPoint animation feature which was used to synchronize coloured text with corresponding highlighted structures on cadaveric images. The order of presentation was designed to guide students through the basic information toward application exercises that placed the anatomy in clinical contexts. Ultimately, progress through the content was student-paced and at the end of each section they were given the opportunity to review the learning outcomes alongside summaries of the related content. An interactive link was also included with each outcome, so the students could easily return to the relevant content within the section for review after they had reflected upon what they had learned and assessed their knowledge to determine if they had successfully met the criteria.
The resource was made available at each of the cadaver stations on laboratory desktop computers throughout the Fall 2016 semester. The different units were stored locally on each computer and were made accessible through an offline website. Since it was not available online, the students were only able to access the CAL resource in the laboratory. However, the students were free to access the resource during all open laboratory hours either on their own or with their peers.

4.3.3.4 Procedures

Aside from items pertaining to CAL resource use, data collection during the Fall 2015 course (see Chapter 3) followed identical procedures to those described herein for the Fall 2016 cohort.

Before the start of the first laboratory session of the Fall 2016 semester, an email was sent to the class mailing list, inviting students to participate in an online survey. The survey contained a demographic questionnaire (see Demographic Profiles in Section 4.3.3.5) and the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F; see Student Approach to Learning in Section 4.3.3.5). In the beginning of the first class, the study was described to the students and they were given a verbal outline of the online survey, information regarding participation, and the opportunity to ask questions about the study. All 296 students in the course were invited to complete the survey and were informed that their participation would earn them a 1% bonus grade on their midterm examination. They were also given the opportunity to complete a short alternate assignment to achieve the bonus grade if they did not wish to participate in the study. The
survey was available during the first ten days of the course via the Qualtrics hosting platform. A reminder to participate was emailed to the students prior to closing the survey.

To quantify week-by-week CAL resource use, the students were asked to complete a brief written questionnaire at the end of each laboratory session. The questionnaire included multiple-choice items asking the students to report if they had used the CAL resource and how they perceived its value to their education (see CAL Resource Use in Section 4.3.3.5).

Finally, the students were invited to participate in a second online survey (or an additional alternate assignment) at the end of the semester for the opportunity to earn a 1% bonus grade on their final examination. This survey package included demographic questions, the R-SPQ-2F, the Course Experience Questionnaire (CEQ; see Course Experience in Section 4.3.3.5), questions about their attendance habits for class and laboratory, and general questions about their overall use and satisfaction with the CAL resource (see CAL Resource Use in Section 4.3.3.5). The survey was available online via Qualtrics for ten days between the last week of class and the final examination. The students were again sent one reminder email prior to closing the survey.

4.3.3.5 Outcome Measures

Demographic Profiles

The participants’ age, sex, program of study, and year of study were collected in the first online survey. Since prior experience in higher education had the potential to
influence SAL, students who were not enrolled in their third year of university were removed from the study (2015, \( n = 30 \); 2016, \( n = 22 \)).

**Course Experience**

To measure each student’s perception of their learning environment, an extended version of the CEQ was used (Ramsden, 1991; Griffin et al., 2003). The CEQ is validated for the evaluation of CE using various items that correspond to specific scales (see Table 3.2 in Chapter 3 for a summary of the CEQ scales and target criteria). Each item was answered on a Likert-type scale with the following five options: ‘definitely disagree’, ‘agree somewhat’, ‘neither agree nor disagree’, ‘agree somewhat’, and 'definitely agree'. Students were asked to evaluate all components of the course as a whole, rather than evaluating individual elements of the course or members of the teaching staff. Scores for each scale were calculated from individual participants’ responses according to McInnis and colleagues (2001).

**Student Approach to Learning**

The R-SPQ-2F, a shortened version of the Study Process Questionnaire (Biggs, 1987), was used to measure SAL on ‘deep’ and ‘surface’ scales from 20 five-point Likert-type questions (Biggs et al., 2001). Participants reported how closely they identified with statements that corresponded to deep learning motives, deep learning strategies, surface learning motives, and surface learning strategies. The motive and strategy responses for each approach type were then combined to produce a respective DA score and SA score, each with minimum possible scores of 10 and maximum possible scores of 50. Higher scores on a given learning approach are indicative of a greater probability that the student
will use that approach during their studies (Biggs et al., 2001). The R-SPQ-2F has been validated for reliability and demonstrates a good fit to its two-factor design (Biggs et al., 2001).

In the first online survey, participants were asked to use the R-SPQ-2F to report their attitudes toward their general studies in university. These initial responses represented their preferred DA (pDA) and preferred SA (pSA) scores (Biggs et al., 2001). In the second online survey, participants used the R-SPQ-2F to report their specific attitudes toward their studies in human anatomy. These responses therefore represented their contextual DA (cDA) and contextual SA (cSA) scores, describing the SAL used specifically in the course (Biggs et al., 2001). The pDA, pSA, cDA, and cSA scores were collected to compare SAL between the 2015 and 2016 cohorts and examine correlations between SAL and their use of the CAL resource, satisfaction with the CAL resource, and overall course performance.

**CAL Resource Use**

In the first online survey, Fall 2016 participants gave informed consent for weekly collection of their reported CAL resource use habits. These weekly surveys were administered to DI and PRO students in the final ten minutes of each laboratory period. The surveys consisted of multiple-choice style questions that asked students to report whether or not they used the CAL resource during that laboratory period (‘yes’ or ‘no’) and rate the usefulness of the CAL resource on a Likert-type scale (see Table 4.1a). These surveys provided a timeline of students' CAL resource use throughout the semester that corresponded to specific course units. Qualitative feedback collected from
these weekly surveys was used to inform future development of the resource but was not analyzed herein.

In the second online survey, Fall 2016 participants responded to an overall CAL resource use questionnaire that asked more general questions about how they used the resource, what they used the resource for, and their perception of the CAL resource as an effective learning tool (see Table 4.1b). Six of the questions were used as items in a ‘CAL Resource Satisfaction (CALRS)’ scale generated for this study (items, potential responses, and associated point-values outlined in Table 4.1b). Responses to these items were averaged to yield a score ranging from -100 to 100 that reflected each student’s experience and satisfaction with the resource. Finally, various open format response items were included for qualitative feedback used to inform improvements to future editions of the CAL resource and to identify themes surrounding the students’ perceptions of the CAL resource and its implementation (see Table 4.1b and Student Feedback, below).

Table 4.1: Summary of the questions targeting the quality and characteristics of computer-assisted learning resource use from (a) in-laboratory and (b) online surveys

<table>
<thead>
<tr>
<th>Category</th>
<th>Question</th>
<th>Response Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAL Resource Use</td>
<td>Did you use the CAL resource today?</td>
<td>a) Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) No</td>
</tr>
<tr>
<td>Qualitative Feedback</td>
<td>How did you perceive the usefulness of the CAL resource?</td>
<td>a) Not useful</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Minimally useful</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Neutral</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d) Somewhat useful</td>
</tr>
<tr>
<td></td>
<td></td>
<td>e) Very useful</td>
</tr>
</tbody>
</table>
### Table 4.1 continued…

**b.**

<table>
<thead>
<tr>
<th>Category</th>
<th>Question</th>
<th>Response Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAL Resource Use Characteristics</td>
<td>Did you use the CAL resource?</td>
<td>a) Yes</td>
</tr>
<tr>
<td></td>
<td>If you answered “b) No”, please explain why.</td>
<td>b) No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Text Response</td>
</tr>
<tr>
<td></td>
<td>What did you use the CAL resource for? Check all that apply.</td>
<td>a) Review</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Laboratory preparation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Laboratory reference</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d) Quiz preparation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>e) Presentation preparation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>f) Exam preparation</td>
</tr>
<tr>
<td>CAL Resource Satisfaction Scale</td>
<td>The CAL resource was a useful tool for anatomy education.</td>
<td>a) Strongly disagree (-100)</td>
</tr>
<tr>
<td>Items</td>
<td>The CAL resource was easy to use.</td>
<td>b) Disagree (-50)</td>
</tr>
<tr>
<td></td>
<td>The CAL resource was easy to understand.</td>
<td>c) Neutral (0)</td>
</tr>
<tr>
<td></td>
<td>The CAL resource complimented the course material.</td>
<td>d) Agree (50)</td>
</tr>
<tr>
<td></td>
<td>The CAL resource enhanced my understanding of the course material.</td>
<td>e) Strongly agree (100)</td>
</tr>
<tr>
<td></td>
<td>The CAL resource helped me to perform better in the course.</td>
<td></td>
</tr>
<tr>
<td>Qualitative Feedback</td>
<td>What did you like about the CAL resource?</td>
<td>Text response</td>
</tr>
<tr>
<td></td>
<td>What did you NOT like about the CAL resource?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Which unit did you find MOST helpful? Why?</td>
<td>a) Back</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) Upper Limb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>c) Thorax</td>
</tr>
<tr>
<td></td>
<td></td>
<td>d) Abdomen</td>
</tr>
<tr>
<td></td>
<td>Which unit did you find LEAST helpful? Why?</td>
<td>Text response</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>How to you think the CAL resource could be improved?</td>
<td>Text response</td>
</tr>
</tbody>
</table>
Academic Performance

The present study used final grades to represent the students’ overall academic achievement in the course. This grade comprised the items outlined in Chapter 3, Table 3.1. Each participant’s cumulative grade average (CGA) from the first two years of their undergraduate degree were obtained with permissions from the UG Office of Institutional Analysis and Research and the UG Research Ethics Board to act as a control variable for student aptitude (Theobald and Freeman, 2014).

Student Feedback

Written student feedback was collected as a part of the second online survey (Table 4.1b). To qualitatively assess the impact of the CAL resource on the students’ perception of their learning environment, a thematic analysis was performed on these responses according to the guidelines described in Braun and Clarke (2006). Specifically, the students’ comments were studied, and initial codes were generated for each comment using an inductive approach. The resulting coded responses were then grouped into their overarching semantic themes and more specific ‘sub-themes’. These themes were reviewed and refined by revisiting the initial written feedback until a set of wholly representative themes was established. Finally, the student feedback was combed for comments that comprehensively represented each theme.

4.3.3.6 Statistical Analyses

Students who did not complete the entire study protocol were removed from the study prior to the analyses. Because DI and PRO involve fundamentally different learning environments and activities, participants were categorized primarily by these groups to
better describe their learning experiences in those contexts. All data were compiled using Microsoft Excel 2016 and statistical analyses were performed using IBM SPSS Statistics software version 25. Normality of data was assessed using the Shapiro-Wilk test and visual inspections of Q-Q plots when appropriate. Significance for all tests was declared at \( p \leq 0.05 \). All data summaries include the mean \((M)\) and standard error of the mean \((SEM)\) unless otherwise stated.

**Demographic Profiles**

Demographic data from 2015 and 2016 students were first compared between the two cohorts to detect potential population differences. Mann-Whitney U tests for non-parametric data were used to compare the average ages and CGAs of Fall 2015 and Fall 2016 students. The distributions of categorical variables, sex and program of study, in each cohort were determined using the chi-squared and Fisher's exact tests of independence, respectively. Age, sex, and program of study were all considered as manifested within the students' SAL scores.

**Historical Comparisons**

Comparisons of CE, SAL, and course performance between Fall 2015 and Fall 2016 cohorts were performed to examine the general outcome differences between years. For CE, participants' CEQ scale scores were calculated by coding responses to yield a mean of zero (i.e., 1 = -100, 2 = -50, 3 = 0, 4 = 50, 5 = 100) (McInnis et al., 2001). Since the CEQ includes some questions that are negatively-worded, those items were reverse coded (i.e., 1 = 100, 2 = 50, 3 = 0, 4 = -50, 5 = -100) for the analyses (McInnis et al., 2001). Each scale was compared between 2015 and 2016 cohorts using the Mann-
Whitney U test for non-parametric data. Perceived course experience was acknowledged as manifested in contextual SAL scores and was therefore excluded from further analyses (Wang et al., 2013). To explore differences in SAL, contextual DA and SA scores were compared between the 2015 and 2016 cohorts using separate one-way analyses of covariance (ANCOVA) for DI and PRO students. To control for preferred SAL, pDA and pSA scores were included as covariates in the respective analyses of cDA and cSA scores. Finally, course performance was also compared between the two cohorts using separate one-way ANCOVAs for DI and PRO students, but with final grades as the dependent variable and CGA serving as the covariate.

**CAL Resource Use in Fall 2016**

Next, CAL resource use was examined in the Fall 2016 cohort, specifically. CAL resource use frequencies were calculated from responses to the weekly CAL resource use surveys outlined in Table 4.1a and expressed as a percentage of laboratory sessions in which the students used the CAL resource. Since each weekly survey corresponded to a specific unit of the course, use frequencies were calculated for each unit as well as for the course overall. These data were then compared between DI and PRO students using the Mann-Whitney U test for non-parametric data. The students’ self-reported reasons for using the CAL resource (reported in the second online survey, Table 4.1b) were grouped into three categories; review, laboratory preparation and reference, and assessment preparation. The proportions of students in who used the CAL resource for these reasons were compared between DI and PRO using Fisher’s exact test. To detect any differences in satisfaction with the resource between DI and PRO students, the
CALRS scale items were used (Table 4.1b). The individual CALRS scale responses were first coded to yield a mean of zero in the same manner as the CEQ scales (McInnis et al., 2001), then combined to yield a CAL resource satisfaction score for each student. Average satisfaction ratings for the CAL resource were compared between DI and PRO students with the Mann-Whitney U test.

Multiple linear regression (MLR) analyses consider several potential explanatory variables jointly and identify the ones that most strongly correlate to the dependent variable while controlling for the others (Theobald and Freeman, 2014). Therefore, MLR analyses were used to determine if any demographic factors significantly influenced the students’ CAL resource use frequency in DI or PRO. The models for DI and PRO both tested the CAL resource use frequency as the dependent variable, while preferred SAL scores, CGA, sex, and program of study were included as potential explanatory variables. Age was excluded because there was a very narrow range among participating students (Table 4.2).

Separate MLRs were also used to examine the influence of the CAL resource on the cDA and cSA scores of Fall 2016 students enrolled in DI and PRO. All four MLRs included the students’ CAL resource use frequencies, reasons for using the CAL resource, and CAL resource satisfaction scores as potential explanatory variables for the dependent variables, cDA and cSA scores. Preferred SAL scores were also included as baseline control variables in all models.
Finally, the students’ final grades were examined for influences from CAL resource use. Separate MLR models for DI and PRO were run to examine the influence of CAL resource use frequency on the dependent variable, final grades, with CGA, cDA, and cSA scores acting as control variables (Theobald and Freeman, 2014). Demographic variables, CEQ scores, reasons for using the CAL resource, and CAL resource satisfaction were acknowledged as manifested in contextual SAL and were therefore excluded from these models (Wang et al., 2013).

4.3.4 Results

4.3.4.1 Demographic Profiles

In total, 191 students (DI = 147, PRO = 44) from the Fall 2015 cohort and 213 students (DI = 182, PRO = 31) from the Fall 2016 semester completed all survey requirements for this study. Among DI students, mean age was significantly different between Fall 2015 (20.19 ± 0.63) and Fall 2016 (20.03 ± 0.46) students ($p = 0.013$). Furthermore, the program of study distribution in DI was significantly different between cohorts ($p = 0.001$). No other variables were significantly different between the two cohorts among DI students (Table 4.2). No statistically significant differences in demographic criteria were found between Fall 2015 and Fall 2016 among PRO students (Table 4.2).
Table 4.2: Summary of demographic profiles within the dissection- and prosection-based laboratory environments during the (a) Fall 2015 and (b) Fall 2016 semesters of the human anatomy course at the University of Guelph

<table>
<thead>
<tr>
<th></th>
<th>Academic Cohort</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall 2015</td>
<td>Fall 2016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Number</td>
<td>147</td>
<td>182</td>
<td></td>
<td></td>
<td>329</td>
</tr>
<tr>
<td>Age (M ± SD; years)</td>
<td>20.19 ± 0.63</td>
<td>20.03 ± 0.46</td>
<td>0.013*</td>
<td>20.10 ± 0.55</td>
<td></td>
</tr>
<tr>
<td>Sex (%)</td>
<td>Male 34.0</td>
<td>33.5</td>
<td>0.924</td>
<td>33.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female 66.0</td>
<td>66.5</td>
<td></td>
<td>66.3</td>
<td></td>
</tr>
<tr>
<td>Program of Study (%)</td>
<td>Human Kinetics</td>
<td>51.7</td>
<td>41.2</td>
<td>45.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biomedical Sciences</td>
<td>44.2</td>
<td>58.8</td>
<td>52.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biological Sciences</td>
<td>4.1</td>
<td>0.0</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Cumulative Grade Average (M ± SD; %)</td>
<td>78.13 ± 7.77</td>
<td>78.76 ± 8.22</td>
<td>0.424</td>
<td>78.48 ± 8.01</td>
<td></td>
</tr>
<tr>
<td>b. Prosection</td>
<td>44</td>
<td>31</td>
<td></td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Age (M ± SD; years)</td>
<td>20.16 ± 0.37</td>
<td>20.19 ± 0.40</td>
<td>0.700</td>
<td>20.17 ± 0.38</td>
<td></td>
</tr>
<tr>
<td>Sex (%)</td>
<td>Male 22.7</td>
<td>22.6</td>
<td>0.988</td>
<td>22.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female 77.3</td>
<td>77.4</td>
<td></td>
<td>77.3</td>
<td></td>
</tr>
<tr>
<td>Program of Study (%)</td>
<td>Human Kinetics</td>
<td>45.5</td>
<td>41.9</td>
<td>44.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biomedical Sciences</td>
<td>50.0</td>
<td>58.1</td>
<td>53.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biological Sciences</td>
<td>4.5</td>
<td>0.0</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>Cumulative Grade Average (M ± SD; %)</td>
<td>78.86 ± 8.31</td>
<td>79.32 ± 8.28</td>
<td>0.914</td>
<td>79.05 ± 8.24</td>
<td></td>
</tr>
</tbody>
</table>

Note. The asterisks (*) denote significance at $p \leq 0.05$.

4.3.4.2 Historical Comparisons

Course Experience

For the comparisons of CEQ scores between Fall 2015 and 2016 in the DI laboratory environment, student perceptions of the teaching ($p = 0.005$), generic skill development ($p = 0.036$), clarity of goals and standards ($p < 0.0005$), learning resources ($p < 0.0005$), and overall course satisfaction ($p = 0.002$) were significantly higher in the Fall 2016 semester than in the Fall 2015 semester (Table 4.3a). For the PRO laboratory environment, Fall 2016 students had significantly higher perceptions of the learning resources ($p < 0.0005$) than Fall 2015 students at the 5% level, while the clarity of goals
and standards \((p = 0.075)\) and overall course satisfaction \((p = 0.051)\) in Fall 2016 were only significantly higher than in Fall 2015 at the 10% level (Table 4.3b).

### Table 4.3: Summary and comparison of Course Experience Questionnaire scores reported by students enrolled in the (a) dissection- and (b) prosection-based laboratory environments during the Fall 2015 and Fall 2016 semesters

<table>
<thead>
<tr>
<th>Scale</th>
<th>Fall 2015 ((M \pm SEM))</th>
<th>Fall 2016 ((M \pm SEM))</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Dissection</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good Teaching</td>
<td>54.82 ± 2.97</td>
<td>65.20 ± 2.25</td>
<td>0.005*</td>
</tr>
<tr>
<td>Generic Skills</td>
<td>36.34 ± 2.80</td>
<td>44.51 ± 2.29</td>
<td>0.036*</td>
</tr>
<tr>
<td>Clear Goals and Standards</td>
<td>32.06 ± 3.46</td>
<td>52.75 ± 2.52</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Appropriate Workload</td>
<td>32.57 ± 2.76</td>
<td>27.34 ± 2.41</td>
<td>0.108</td>
</tr>
<tr>
<td>Appropriate Assessment</td>
<td>22.90 ± 2.94</td>
<td>17.40 ± 2.53</td>
<td>0.101</td>
</tr>
<tr>
<td>Learning Resources</td>
<td>49.12 ± 2.57</td>
<td>67.47 ± 1.94</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td><strong>Overall Satisfaction</strong></td>
<td>74.15 ± 3.29</td>
<td>86.54 ± 1.94</td>
<td>0.002*</td>
</tr>
<tr>
<td><strong>b. Prosection</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good Teaching</td>
<td>56.63 ± 4.38</td>
<td>65.86 ± 5.00</td>
<td>0.168</td>
</tr>
<tr>
<td>Generic Skills</td>
<td>31.06 ± 4.53</td>
<td>40.86 ± 5.35</td>
<td>0.129</td>
</tr>
<tr>
<td>Clear Goals and Standards</td>
<td>42.05 ± 5.41</td>
<td>56.05 ± 5.08</td>
<td>0.075</td>
</tr>
<tr>
<td>Appropriate Workload</td>
<td>37.50 ± 4.88</td>
<td>41.53 ± 6.41</td>
<td>0.576</td>
</tr>
<tr>
<td>Appropriate Assessment</td>
<td>33.33 ± 4.88</td>
<td>24.19 ± 6.51</td>
<td>0.230</td>
</tr>
<tr>
<td>Learning Resources</td>
<td>53.41 ± 4.09</td>
<td>76.13 ± 3.24</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td><strong>Overall Satisfaction</strong></td>
<td>78.41 ± 5.95</td>
<td>93.55 ± 3.06</td>
<td>0.051</td>
</tr>
</tbody>
</table>

**Note.** Asterisks (*) denote significance at \(p \leq 0.05\).

**Student Approach to Learning**

There was a statistically significant difference in cDA scores between the 2015 and 2016 cohorts in both the DI \([F(1,326) = 15.896, p < 0.0005, \text{partial } \eta^2 = 0.046]\) and PRO \([F(1,72) = 6.967, p = 0.010, \text{partial } \eta^2 = 0.088]\) laboratories. Specifically, 2016 students had statistically significantly lower cDA scores than 2015 students in both DI and PRO laboratories (see Table 4.4a). Conversely, the comparisons of cSA scores between 2015 and 2016 students in DI \([F(1,326) = 12.409, p < 0.0005, \text{partial } \eta^2 = 0.037]\) and PRO \([F(1,72) = 14.372, p < 0.0005, \text{partial } \eta^2 = 0.166]\) found that 2016 students in both laboratory environments had significantly higher cSA scores than students from the 2015 cohort (Table 4.4b).
Table 4.4: Comparisons of contextual (a) deep approach and (b) surface approach scores between Fall 2015 and Fall 2016 students enrolled in dissection and prosection

### a. Contextual Deep Approach Scores

<table>
<thead>
<tr>
<th>Cohort</th>
<th>N</th>
<th>Unadjusted (M ± SD)</th>
<th>Adjusted (M ± SEM)</th>
<th>Mean Difference (M ± SEM, p)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dissection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2015</td>
<td>147</td>
<td>34.95 ± 5.99</td>
<td>35.09 ± 0.39</td>
<td>- 2.11 ± 0.53, &lt; 0.0005*</td>
</tr>
<tr>
<td>Fall 2016</td>
<td>182</td>
<td>33.10 ± 6.36</td>
<td>32.99 ± 0.35</td>
<td></td>
</tr>
<tr>
<td><strong>Prosection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2015</td>
<td>44</td>
<td>33.41 ± 5.37</td>
<td>33.27 ± 0.66</td>
<td>- 2.72 ± 1.03, 0.010*</td>
</tr>
<tr>
<td>Fall 2016</td>
<td>31</td>
<td>30.35 ± 5.70</td>
<td>30.55 ± 0.79</td>
<td></td>
</tr>
</tbody>
</table>

*Adjusted values represent the model with pDA score as a covariate.

### b. Contextual Surface Approach Scores

<table>
<thead>
<tr>
<th>Cohort</th>
<th>N</th>
<th>Unadjusted (M ± SD)</th>
<th>Adjusted (M ± SEM)</th>
<th>Mean Difference (M ± SEM, p)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dissection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2015</td>
<td>147</td>
<td>23.06 ± 5.82</td>
<td>23.09 ± 0.41</td>
<td>1.95 ± 0.55, &lt; 0.0005*</td>
</tr>
<tr>
<td>Fall 2016</td>
<td>182</td>
<td>25.07 ± 6.07</td>
<td>25.05 ± 0.37</td>
<td></td>
</tr>
<tr>
<td><strong>Prosection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2015</td>
<td>44</td>
<td>22.68 ± 5.84</td>
<td>22.61 ± 0.71</td>
<td>4.16 ± 1.10, &lt; 0.0005*</td>
</tr>
<tr>
<td>Fall 2016</td>
<td>31</td>
<td>26.68 ± 6.16</td>
<td>26.77 ± 0.84</td>
<td></td>
</tr>
</tbody>
</table>

*Adjusted values represent the model with pSA score as a covariate.

**Note.** Asterisks (*) denote significance at \( p \leq 0.05 \).

**Academic Performance**

Final grades were significantly different between 2015 and 2016 students enrolled in PRO \([F(1,72) = 9.980, p = 0.002, \text{partial } \eta^2 = 0.122]\) but not in DI \([F(1,326) = 0.791, p = 0.375, \text{partial } \eta^2 = 0.002]\). Pairwise comparisons further revealed that final grades were higher in 2016 than in 2015, despite controlling for CGA (Table 4.5).
Table 4.5: Pairwise comparisons of final grades between Fall 2015 and Fall 2016 students enrolled in dissection and prosection

<table>
<thead>
<tr>
<th>Cohort</th>
<th>N</th>
<th>Unadjusted (M ± SD)</th>
<th>Adjusted (M ± SEM)</th>
<th>Mean Difference (M ± SEM, p)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dissection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2015</td>
<td>147</td>
<td>87.77 ± 7.34</td>
<td>87.97 ± 0.46</td>
<td>0.55 ± 0.62, 0.375</td>
</tr>
<tr>
<td>Fall 2016</td>
<td>182</td>
<td>88.68 ± 7.20</td>
<td>88.52 ± 0.41</td>
<td></td>
</tr>
<tr>
<td><strong>Prosection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2015</td>
<td>44</td>
<td>86.27 ± 7.26</td>
<td>86.38 ± 0.69</td>
<td>3.39 ± 1.07, 0.002*</td>
</tr>
<tr>
<td>Fall 2016</td>
<td>31</td>
<td>89.91 ± 4.90</td>
<td>89.77 ± 0.82</td>
<td></td>
</tr>
</tbody>
</table>

Adjusted values represent the model with CGA as a covariate.

Note. The asterisk (*) denotes significance at \( p \leq 0.05 \).

4.3.4.3 CAL Resource Use in Fall 2016

For CAL resource use, the weekly laboratory survey responses (Figure 4.1) revealed different usage patterns between DI and PRO students throughout the semester. During the weeks that correlated with the back unit, significantly more PRO students (64.52% ± 5.28) used the CAL resource than DI students (39.56% ± 2.81; \( p < 0.0005 \)). Conversely, during the abdomen unit, more DI students (35.71% ± 2.13) used the CAL resource than PRO students (19.36% ± 4.31; \( p = 0.003 \)). Overall CAL use throughout the entire semester, however, was not significantly different between DI (35.81% ± 1.47) and PRO students (36.66% ± 2.84; \( p = 0.765 \)).
Figure 4.1: Percentage of dissection and prosection students who used the computer-assisted learning resource during each unit of the Fall 2016 course
1. Error bars represent the standard error of the mean
2. The asterisks (*) denote significant differences between DI and PRO groups at $p \leq 0.05$

Differences were also present in the students’ reasons for using the CAL resource between DI and PRO (Figure 4.2). The vast majority of both DI (86.06%) and PRO (90.00%) students reported using the resource for review; however, significantly more DI students (67.88%) reported using the CAL resource for laboratory preparation and reference than PRO students (36.67%; $p = 0.002$).
Figure 4.2: Proportion of dissection and prosection students who reported using the computer-assisted learning resource for review, laboratory preparation and reference, and assessment preparation during the Fall 2016 semester

1. The asterisk (*) denotes a significant difference between DI and PRO groups at $p \leq 0.05$

The CALRS scale was tested using Cronbach’s $\alpha$ and found to have good fit and reliability (0.84). Average satisfaction ratings for the CAL resource did not significantly differ between DI (77.78 ± 2.06) and PRO (71.39 ± 4.18) students ($p = 0.072$).

In both the DI cohort [$F(5,181) = 2.691$, $p = 0.023$, $R^2 = 0.071$] and the PRO cohort [$F(5,30) = 1.090$, $p = 0.390$, $R^2 = 0.179$], none of the potential explanatory variables had statistically significant correlations with CAL resource use frequency according to MLR analyses (Table 4.6).
Table 4.6: Multiple linear regression analyses of the influences of demographic presage factors and student approaches to learning on computer-assisted learning resource use in dissection and prosection cohorts during Fall 2016

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$SE_B$</th>
<th>$B'$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Dissection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL Resource Use Frequency (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>5.482</td>
<td>2.656</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Deep Approach Score</td>
<td>0.049</td>
<td>0.029</td>
<td>0.129</td>
<td>0.100</td>
</tr>
<tr>
<td>Preferred Surface Approach Score</td>
<td>0.009</td>
<td>0.032</td>
<td>0.022</td>
<td>0.775</td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>-0.042</td>
<td>0.026</td>
<td>-0.160</td>
<td>0.107</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>-0.347</td>
<td>0.338</td>
<td>-0.075</td>
<td>0.306</td>
</tr>
<tr>
<td>Program of Study (HK)</td>
<td>0.467</td>
<td>0.427</td>
<td>0.106</td>
<td>0.276</td>
</tr>
<tr>
<td><strong>b. Prosection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CAL Resource Use Frequency (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>-0.279</td>
<td>5.159</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Deep Approach Score</td>
<td>0.114</td>
<td>0.074</td>
<td>0.306</td>
<td>0.139</td>
</tr>
<tr>
<td>Preferred Surface Approach Score</td>
<td>-0.056</td>
<td>0.060</td>
<td>-0.179</td>
<td>0.358</td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>0.009</td>
<td>0.047</td>
<td>0.042</td>
<td>0.855</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>1.365</td>
<td>0.828</td>
<td>0.333</td>
<td>0.112</td>
</tr>
<tr>
<td>Program of Study (HK)</td>
<td>0.682</td>
<td>0.791</td>
<td>0.196</td>
<td>0.397</td>
</tr>
</tbody>
</table>

**Note.** The reference level for sex is male. Program of study represents HK in reference to all other programs. $B = \text{unstandardized regression coefficient}; \ SE_B = \text{standard error of the coefficient}; \ B' = \text{standardized coefficient}; \ p = \text{statistical significance of } B'$. 

**Student Approach to Learning**

Among both DI [$F(7,164) = 19.752, \ p < 0.0005, \ R^2 = 0.468$] and PRO students [$F(7,29) = 3.800, \ p = 0.008, \ R^2 = 0.547$], cDA scores were found to be significantly influenced by CAL resource satisfaction scores (DI, $p = 0.001$; PRO, $p = 0.025$) and the control variable, pDA scores (DI, $p < 0.0005$; PRO, $p = 0.002$). However, only pSA scores ($p < 0.0005$), contributed significantly to the prediction of cSA scores among PRO students [$F(7,29) = 5.734, \ p = 0.001, \ R^2 = 0.646$], while both pDA ($p = 0.023$) and pSA scores ($p < 0.0005$) were statistically significant predictors of cSA scores among DI students [$F(7,164) = 12.560, \ p < 0.0005, \ R^2 = 0.359$]. Correlation coefficients and significance values for all potential explanatory variables are outlined in Table 4.7.
Table 4.7: Multiple linear regression analyses of the influences of computer-assisted learning resource use and satisfaction on deep and surface learning approach scores in dissection- and prosection-based cohorts during Fall 2016

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE_b</th>
<th>B'</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Dissection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contextual Deep Approach Score (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>8.084</td>
<td>3.445</td>
<td>0.586*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Preferred Deep Approach Score</td>
<td>0.635</td>
<td>0.068</td>
<td>0.586*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Preferred Surface Approach Score</td>
<td>0.002</td>
<td>0.072</td>
<td>0.002</td>
<td>0.975</td>
</tr>
<tr>
<td>CAL Resource Use Frequency</td>
<td>0.151</td>
<td>0.187</td>
<td>0.050</td>
<td>0.420</td>
</tr>
<tr>
<td>Reasons for CAL Resource Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review</td>
<td>1.150</td>
<td>1.104</td>
<td>0.063</td>
<td>0.299</td>
</tr>
<tr>
<td>Laboratory Preparation and Reference</td>
<td>-1.097</td>
<td>0.800</td>
<td>-0.081</td>
<td>0.172</td>
</tr>
<tr>
<td>Assessment Preparation</td>
<td>-1.032</td>
<td>0.817</td>
<td>-0.078</td>
<td>0.208</td>
</tr>
<tr>
<td>CAL Resource Satisfaction</td>
<td>0.049</td>
<td>0.015</td>
<td>0.202*</td>
<td>0.001*</td>
</tr>
<tr>
<td>Contextual Surface Approach Score (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>14.925</td>
<td>3.632</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Deep Approach Score</td>
<td>-0.164</td>
<td>0.072</td>
<td>-0.158*</td>
<td>0.023*</td>
</tr>
<tr>
<td>Preferred Surface Approach Score</td>
<td>0.571</td>
<td>0.076</td>
<td>0.507*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>CAL Resource Use Frequency</td>
<td>0.263</td>
<td>0.197</td>
<td>0.091</td>
<td>0.184</td>
</tr>
<tr>
<td>Reasons for CAL Resource Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review</td>
<td>-0.134</td>
<td>1.164</td>
<td>-0.008</td>
<td>0.908</td>
</tr>
<tr>
<td>Laboratory Preparation and Reference</td>
<td>1.009</td>
<td>0.843</td>
<td>0.077</td>
<td>0.233</td>
</tr>
<tr>
<td>Assessment Preparation</td>
<td>1.136</td>
<td>0.861</td>
<td>0.090</td>
<td>0.189</td>
</tr>
<tr>
<td>CAL Resource Satisfaction</td>
<td>-0.001</td>
<td>0.016</td>
<td>-0.003</td>
<td>0.962</td>
</tr>
<tr>
<td><strong>b. Prosection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contextual Deep Approach Score (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>-8.204</td>
<td>9.185</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Deep Approach Score</td>
<td>0.712</td>
<td>0.208</td>
<td>0.540</td>
<td>0.002*</td>
</tr>
<tr>
<td>Preferred Surface Approach Score</td>
<td>0.180</td>
<td>0.149</td>
<td>0.184</td>
<td>0.240</td>
</tr>
<tr>
<td>CAL Resource Use Frequency</td>
<td>0.841</td>
<td>0.551</td>
<td>0.268</td>
<td>0.142</td>
</tr>
<tr>
<td>Reasons for CAL Resource Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review</td>
<td>2.759</td>
<td>2.771</td>
<td>0.153</td>
<td>0.330</td>
</tr>
<tr>
<td>Laboratory Preparation and Reference</td>
<td>-0.123</td>
<td>1.650</td>
<td>-0.011</td>
<td>0.941</td>
</tr>
<tr>
<td>Assessment Preparation</td>
<td>-1.415</td>
<td>1.824</td>
<td>-0.130</td>
<td>0.446</td>
</tr>
<tr>
<td>CAL Resource Satisfaction</td>
<td>0.088</td>
<td>0.037</td>
<td>0.367</td>
<td>0.025*</td>
</tr>
<tr>
<td>Contextual Surface Approach Score (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>18.120</td>
<td>9.214</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Deep Approach Score</td>
<td>-0.097</td>
<td>0.209</td>
<td>-0.065</td>
<td>0.648</td>
</tr>
<tr>
<td>Preferred Surface Approach Score</td>
<td>0.757</td>
<td>0.149</td>
<td>0.682*</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>CAL Resource Use Frequency</td>
<td>-0.399</td>
<td>0.553</td>
<td>-0.112</td>
<td>0.479</td>
</tr>
<tr>
<td>Reasons for CAL Resource Use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review</td>
<td>-2.012</td>
<td>2.780</td>
<td>-0.098</td>
<td>0.477</td>
</tr>
</tbody>
</table>
Table 4.7 continued…

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE_B</th>
<th>B'</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Preparation and Reference</td>
<td>-0.053</td>
<td>1.655</td>
<td>-0.004</td>
<td>0.975</td>
</tr>
<tr>
<td>Assessment Preparation</td>
<td>-0.800</td>
<td>1.830</td>
<td>-0.065</td>
<td>0.666</td>
</tr>
<tr>
<td>CAL Resource Satisfaction</td>
<td>-0.041</td>
<td>0.037</td>
<td>-0.148</td>
<td>0.282</td>
</tr>
</tbody>
</table>

Note. Categorical variables representing Reasons for CAL Resource Use compare participants who used the resource for that reason against those who did not; B = unstandardized regression coefficient; SE_B = standard error of the coefficient; B' = standardized coefficient; p = statistical significance of B'; asterisks (*) denote significance at p ≤ 0.05.

Academic Performance

The results of separate MLR models run to examine the influence of CAL resource use frequency on final grades in DI and PRO are presented in Table 4.8. For both DI students \(F(4,181) = 28.904, p < 0.0005, R^2 = 0.395\) and PRO students \(F(4,30) = 5.936, p = 0.002, R^2 = 0.477\), neither cDA scores nor CAL resource use frequency had a statistically significant correlation with final grades (Table 4.8); however, a statistically significant negative relationship was found between cSA scores and final grades \(p = 0.048\) among DI students (Table 4.8a).

Table 4.8: Multiple linear regression analyses of the influences of computer-assisted learning resource use on final course grades in dissection- and prosection-based cohorts during Fall 2016

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE_B</th>
<th>B'</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Dissection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Grade (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>49.377</td>
<td>5.309</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>0.533</td>
<td>0.053</td>
<td>0.608</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.018</td>
<td>0.071</td>
<td>0.016</td>
<td>0.799</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>-0.146</td>
<td>0.471</td>
<td>-0.123</td>
<td>0.048*</td>
</tr>
<tr>
<td>CAL Resource Use Frequency</td>
<td>0.100</td>
<td>0.030</td>
<td>0.364</td>
<td>0.621</td>
</tr>
<tr>
<td>b. Proection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Grade (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>60.222</td>
<td>9.784</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative Grade Average</td>
<td>0.336</td>
<td>0.094</td>
<td>0.567</td>
<td>0.001*</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.164</td>
<td>0.134</td>
<td>0.191</td>
<td>0.233</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>-0.082</td>
<td>0.129</td>
<td>-0.103</td>
<td>0.531</td>
</tr>
<tr>
<td>CAL Resource Use Frequency</td>
<td>0.064</td>
<td>0.452</td>
<td>0.023</td>
<td>0.888</td>
</tr>
</tbody>
</table>

Note. B = unstandardized regression coefficient; SE_B = standard error of the coefficient; B' = standardized coefficient; p = statistical significance of B'; asterisks (*) denote significance at p ≤ 0.05.
Student Feedback

The thematic analysis of the students’ written feedback identified several common themes that outlined both the benefits and drawbacks of the CAL resource and how it was incorporated into the course. The tool was widely considered to be valuable for review and laboratory reference, and students expressed positivity toward the recontextualization of course information within the tutorials, the depth and clarity with which information was presented, and the alignment between the CAL resource and the other components of the course (Table 4.9a). Conversely, many students felt that the alignment between the resource and the other elements of the course (especially the assessments) could have been stronger (Table 4.9b). Other notable perceived drawbacks of the resource were its lack of accessibility outside of the laboratory and various aspects of the content and design of the tutorials (Table 4.9b). See Table 4.9 for an overview of the themes and sample comments that demonstrate the characteristics of each theme.
Table 4.9: Resulting themes from thematic analyses of student feedback on the computer-assisted learning resource and its implementation during Fall 2016

<table>
<thead>
<tr>
<th>Theme</th>
<th>Example Student Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Benefits</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Review | • “[The CAL resource] was great to review the body of information taught in class. Overall, it was like a quick crash course that I found pretty useful.”  
• “I liked that [the CAL resource] was an opportunity to review course material at my own pace.” |
| Reference | • “I liked that it was a recap […] with real donor pictures so you could see it and compare the structure to your donor on the table. [The CAL resource] really helped me with my identification/prep for the [laboratory tests].”  
• “[The CAL resource] helped to answer questions when TAs weren't always available.” |
| Recontextualization | • “[The CAL resource] gave us applied scenarios so that we could see if we really understood a concept.”  
• “[The CAL resource] was a really nice way to study topics from a new perspective.”  
• “[The CAL resource] helped explain things in a different way then how it was taught in lecture.” |
| Depth and Clarity | • “I liked the level of detail in the tutorials, the perfect amount for what we needed to know.”  
• “Information was presented in a clear and effective manner.”  
• “[The CAL resource tutorials] were clear, concise, and organized well which made them easy to follow.” |
| Alignment | • “[The CAL resource tutorials] were 100% reflective of what was taught in lecture.”  
• “[The CAL resource was] directly in line with the course, unlike the textbook which can sometimes give too much info.”  
• “[The CAL resource] helped me connect to what I learned in class with what I was looking at in dissection.” |
| **b. Drawbacks** | |
| Accessibility | • “It would be much more convenient if [the CAL resource was] viewable from home.”  
• “Too much work need to be done with dissecting. I preferred learning by discovery rather than trying to memorize things that we had not yet found in our donor. We spent our time looking at the bodies instead. Make [the CAL resource] available outside the lab!”  
• “Not everyone can access [the CAL resource]. I feel like I am in the hunger games when I am trying to get a computer sometimes – there’s so many people and not enough computers. Put it online!”  
• “Sometimes [the CAL resource was] not always up to date with what concepts had been presented in class. But typically, by the end of the week they would be available.” |
Table 4.9 continued…

| Content and Design | • “Add quiz components to test the user’s knowledge and drill in important concepts.”
|• “It was hard at times to navigate through the material. Perhaps the ability to search for key concepts or terms or a jump bar to navigate simply between slides could be included.”
|• “Some were very long, and not that engaging to read. Maybe increase speed of the animations? Or increase details, or perhaps have it in a format where you can access the part you specifically need. Many smaller sections instead of one big section would be nice.” |

| Alignment | • “Although interesting, some information did not follow exactly what was taught in lecture, so I think there could be more consistency between what is taught in lecture and what is contained in the [CAL resource].”
|• “[The CAL resource tutorials] were sometimes inconsistent with the level of detail we were taught in class leaving some confusion over what level of detail we were expected to know.”
|• “Addition of information that was not going to be tested. Extra information was annoying when trying to memorize and understand what was taught.” |

4.3.5 Discussion

The goal of this study was to evaluate the pedagogical impact of a novel CAL resource that was introduced into the laboratory of a third-year undergraduate human anatomy course at UG during the Fall 2016 semester. By examining the relationships between students’ use of the CAL resource, CE, SAL, and ultimate course performance, this study determined that the CAL resource, as it was implemented herein, did not influence student performance and may have even been detrimental to the goal of promoting meaningful learning. Surprisingly, these findings came despite the students’ overwhelmingly positive perceptions of the tool and its value. This study contributes to a larger discussion on CAL among human anatomy educators and illustrates how determining the most appropriate learning context is an important consideration for the successful implementation of CAL resources (Losco et al., 2017).
In the present study, the integration of the CAL resource into the laboratory component of the course altered the learning environment and therefore merited investigation into its effect on SAL in the course (Biggs, 1987). Because of the educational value associated with DAs to learning (van Rossum and Schenk, 1984; Trigwell and Prosser, 1991; Newstead, 1992; Gibbs, 1994; Norton and Dickens, 1995; McCune and Entwistle, 2000; Zimitat and McAlpine, 2003; Wilson and Fowler, 2005; Pandey and Zimitat, 2007), this resource was aimed at encouraging DAs among students in both the DI and PRO laboratories. It was expected that students would use the CAL resource as a basic anatomical reference to build a stronger knowledge-base, allowing them to pursue higher-order learning techniques associated with DAs to learning in the laboratory; however, the opposite effect was seen. The present study instead found that students from the 2016 cohort (with access to the CAL resource) had significantly higher cSA scores and significantly lower cDA scores than students from the 2015 cohort (without access to the CAL resource) (Table 4.4), despite all other elements of the course remaining the same. These findings suggest that the inclusion of the CAL resource in the Fall 2016 human anatomy laboratory and the resulting changes to the course environment encouraged surface-level study approaches and suppressed the students’ use of deeper learning strategies. This change was especially prominent in PRO, with 2016 PRO students reporting mean cSA scores that were over four points higher than 2015 students (Table 4.4b). This outcome was particularly surprising, given past results indicating that participation in a cadaver-based course encouraged DAs among DI students and discouraged SAs among PRO students (Chapter 3), and reports that
suggested CAL use was associated with DAs to learning (Zimitat and McAlpine, 2003; Knight, 2010). To add further intrigue, 2016 PRO students performed significantly better in the course than 2015 PRO students (Table 4.5). However, since these broad historical comparisons between two different academic cohorts did not account for individual resource use characteristics, the findings should be interpreted with caution.

One possible explanation for the unexpected changes in SAL is that the CAL tool was perceived as a time investment that distracted from the cadavers. Many students prioritized the cadavers and their TAs as important learning resources associated with their laboratory experience (Table 4.9b) and viewed the cadaveric element as a ‘rite of passage’ into their health-related careers (Dinsmore et al., 1999). Further reasons for limiting CAL resource use implied that there was too much content that needed to be learned from the cadaveric specimens to waste laboratory time with a digital learning tool (Table 4.9b). This feedback implies that many students may have perceived the cumulative course workload to be overwhelming, which (alongside negative perceptions of the course assessments) has been implicated as a driver toward more of a SA to learning (Prosser and Trigwell, 2000; Lizzio et al., 2002; Entwistle and Peterson, 2004; Cano et al., 2018; Chapter 3). While lower scores on the Appropriate Workload scale of the CEQ in 2016 (although non-significant) suggest that this may have been an issue for DI students, the opposite trend was seen among PRO students (Table 4.3). However, the 2016 students in both DI and PRO rated the appropriateness of the course assessments lower than the 2015 students did, indicating a perception that the course was focused more on surface-level outcomes in 2016 than in previous course cycles (Ramsden, 1991)
(Table 4.3). However, since this trend was not significant, the curriculum and assessments did not drastically change between the two years, and neither cDA nor cSA scores were significantly associated with CAL resource use frequency, it is unclear what drove this difference. Some student comments implied that the CAL resource was seen as more of a surface learning implement than the other available resources (Table 4.9b). Furthermore, informal comments from experienced TAs implied that more recent cohorts of students may have used the resource to be ‘spoon-fed’ the relevant information without deeply engaging with the material. This attitude has been reported by several educational researchers over recent decades (Ramsden, 1992; McLachlan, 2006; Raelin, 2009; Wood, 2009; Wormald et al., 2009; Burns, 2010; Dehler and Welsh, 2014; Thompson et al., 2016) and may have contributed to the differences in SAL observed between the 2015 and 2016 cohorts; however, it hints at a larger systemic problem in education that is outside the scope of this work.

Since use of the CAL resource did not have a significant positive or negative correlation with SAL (Table 4.7) or performance (Table 4.8), its effects on learning may have been more nuanced. Students’ enjoyment, engagement, and motivation have been suggested as important contributors to learning (Brophy, 2013; Burgess and Ramsey-Stewart, 2015); however, several studies in human anatomy education have reported that students enjoyed CAL even though it was shown not to have improved their overall learning (Hopkins et al., 2011; Codd and Choudhury, 2011; Stirling and Brit, 2014). Feedback from participants in this study indicated that the CAL resource was predominantly viewed as an enjoyable and valuable learning tool in both the DI and PRO
laboratories (Table 4.9a). These positive attitudes toward CAL were echoed in their satisfaction ratings for the laboratory resources, which were positive and high in both DI and PRO. Furthermore, 2016 students rated the course significantly higher on the Learning Resources scale of the CEQ than students from the Fall 2015 semester in both DI and PRO (Table 4.3). These scores likely reflect the students’ attitudes toward the CAL tool since it was the sole difference in the available resources between the two years. While scores on the Learning Resources scale were not significantly correlated to SAL in past analyses (Chapter 3), students who reported higher satisfaction with the CAL resource itself adopted deeper approaches to learning in this study (Table 4.7). Ultimately, these findings showed that it is not how or how often the students used the resource that dictated its effect on learning, but whether they felt it was a strategy that would help them to reach their learning goals. Some have suggested that such positive perceptions may be more encouraging toward DAs to learning than the objective resource itself (Meyer et al., 1990; Trigwell and Prosser, 1991). This, however, should not be mistaken as a finding that supports defunct learning style theory (Hussmann and O’Loughlin, 2018), but rather as an argument for student choice and motivation. Millennial students have demonstrated a preference for flexibility and choice in their learning (Petit et al., 2017; Whelan et al., 2018). Thus, by offering the current student generation a variety of resources, they are more likely to find and use the ones that engage them and motivate them to learn the content. While the ways students choose to study are not always beneficial to their learning (Hussmann and O’Loughlin, 2018), increasing their motivation to learn can have a powerful impact on the outcome and should therefore be
a prominent goal of higher education (Kusurkar et al., 2011; Burgess and Ramsey-Stewart, 2015).

The original goal of implementing this CAL resource was to give the students a comprehensive, aligned, and accessible reference tool that would promote self-directed learning behaviours and help them to develop their basic anatomical knowledge, allowing them to pursue higher-order learning activities in the laboratory. Since these outcomes align with a characteristically DA to learning (Reeves et al., 2004; Findlater et al., 2012; Brophy, 2013), it was hypothesized that students who used the CAL resource more frequently for laboratory preparation and reference would adopt higher cDA scores; however, as previously discussed, this was not the case (Table 4.7). This result may to some extent reflect the context in which the resource was disseminated. While some student feedback did imply that the CAL tool provided a valuable in-lab resource (Table 4.9a), a stronger reoccurring theme also emerged. Over 120 participants indicated that they would rather have access to the CAL resource online so that they could prepare for their laboratory sessions and review the content at home before written and laboratory examinations (Table 4.9b). These comments unveiled the students’ desire for what is essentially a ‘flipped’ laboratory structure. Flipped designs are increasing in popularity, usually as a modification to classroom-based environments (Lage et al., 2000; Lage and Platt, 2000; Bergmann and Sams, 2009; O’Flaherty and Phillips, 2015; Hew and Lo, 2018). These designs often employ blended learning techniques in which students partake in both face-to-face and online learning activities (O’Flaherty and Phillips, 2015; Hew and Lo, 2018). Structuring the course in this manner would allow the students to
arrive at the face-to-face sessions with more prior knowledge of the content and procedures that they are expected expand upon in the laboratory, which is intimately linked to their achievement (Hailikari et al., 2008). Prior knowledge has also been tied to higher levels of knowledge retention and learning quality, such as the students’ ability to apply what they know (Dirkx et al., 2014). Flipped designs also offer the opportunity to incorporate self-testing components (Hew and Lo, 2018), which have been shown to enhance memory and knowledge retention in various disciplines including anatomy and physiology (Roediger and Karpicke, 2006; Dobson and Linderholm, 2015a). In their feedback, the students expressed a desire for more interactivity of this nature in the resource, also suggesting better alignment and navigation options to improve usability (Table 4.9b). Free navigation and curricular alignment are hallmark features of well-designed multimedia tools that intend to support self-directed learning (Mayer and Moreno, 2003; Biggs and Tang, 2011). Therefore, by adapting the current CAL resource to incorporate these suggestions and making it available as an online study tool, the program can more effectively flip the laboratory and perhaps improve students’ laboratory preparedness and overall learning success.

4.3.5.1 Limitations

Learning is a difficult process to quantify. Accordingly, this study was subject to various potential confounds presented by the course design and research population – the most acute of which was tracking the students’ use of the CAL resource. Various approaches for recording the frequency and characteristics of the students’ resource use were considered, including having them log-in to view the program. However, the main
objective was to observe and report how the students naturally used the resource and how it fit into the existing learning environment. The research team felt that individual students would have been unlikely to log in and out of the system between uses when sharing the computer station with their group members, leading to the collection of inaccurate use data for individual students. Furthermore, requiring a log-in for each use may have dissuaded some students from using the resource and created a selection-type bias. Ultimately, the decision was made to abandon the log-in approach and rely upon student-reported data to evaluate their behaviours. This, however, may have led to reduced participation numbers. Only 77.4% of DI students and 50.8% of PRO students participated in every survey for this study. It is therefore possible that the volume of surveys required to measure weekly CAL resource use deterred some students from participating. With a more accurate and less demanding way of tracking each students’ module use, participation may have been higher and more representative trends may have emerged. Some students were also removed from the study because they were not enrolled in their third year of university (2015, $n = 30$; 2016, $n = 22$). This was done to normalize the amount of higher-education experience the students were exposed to prior to the course. This allowed for more accurate comparisons of SAL and a closer depiction of the target demographic for the third-year course (Biggs et al., 2001).

Another important factor that was not measured for this study was attendance and CAL resource use during the extra open-laboratory hours. Throughout the semester, students were able to access the laboratory and its associated resources to study or work on their dissections during these open hours. Unfortunately, attendance and CAL
resource use were not consistently or accurately tracked during these sessions. It is therefore possible that CAL resource use was not accurately reported for some students.

Finally, the types of assessments employed in this course may not have accurately reflected the more qualitative aspects of learning such as skill development. The different course assessments (outlined in Chapter 3, Table 3.1) were considered as metrics for various independent elements of academic performance; however, the trends observed in those analyses (data not shown) did not contribute to a better understanding of the effects of the CAL resource. Ultimately, the same trends were observed in the analyses on final grades (Table 4.8). Since DA to learning are typically associated with qualitative learning outcomes, assessments that better target skills and skill development should be considered in the future.

4.3.5.2 Future Directions

An obvious continuation for this project is to make the CAL resource available to the students outside of the laboratory to observe how it influences their preparedness for the laboratory sessions and course assessments. Future iterations of the resource will also include quiz components that allow the students to pre-test their knowledge and can also be viewed by the instructor to gauge the students’ level of prior understanding. These such quiz components are crucial elements to the success of a flipped design (Dobson and Linderholm, 2015a; Hew and Lo, 2018). Additional research pertaining to this CAL resource will examine more skill-based outcomes to better determine if the resource influenced the quality of student learning. This may also include analyses of specific written and laboratory test questions to determine if there are correlations or differences
between CAL resource use and performance on questions that assess high- or low-level outcomes (Thompson and O’Loughlin, 2015). Future research should also be conducted to directly compare how CAL resources are used in DI and PRO to better inform the approach used to teach anatomy in those environments from the administrator, instructor, and student perspectives.

In addition to the new research questions that have arisen out of this study, various areas for the development and improvement of the resource were discovered. These insights will be used to inform the creation of CAL tutorials that cover the content discussed in the second-half of the course, including the pelvis, lower limb, head, and neck regions. A long-term goal of the program is to use the CAL resource to develop a ‘virtual cadaver-based laboratory’ to compliment a future open online human anatomy course for students in different majors. Currently, UG does not offer a basic anatomy course outside of the one assessed in this study. Although some students from non-science majors are permitted to enroll in the primary third-year human anatomy course with instructor consent (given available space), many others must seek anatomy courses at other institutions. Therefore, using these and the future installments of the CAL resource to develop an online human anatomy course at UG would give students a local option for detailed anatomy education.

4.3.6 Conclusions

Improving learning quality in resource-challenged climates is a primary pursuit of most laboratory-based human anatomy programs. UG recently implemented a curriculum-based CAL resource that was intended to promote self-directed learning
behaviours and encourage DAs to learning among DI and PRO students. This work analyzed various outcomes to determine how the CAL resource affected learning within these laboratories and the in the course overall. The study found that SAL and performance were not directly influenced by CAL resource use; however, students who had a positive perception of the resource adopted stronger DAs to learning. In general, students had lower DA scores and higher SA scores when the CAL resource was included in the course, despite the tool receiving universal praise from the students. The student feedback illustrated that the context in which CAL resources are disseminated should be a primary consideration when incorporating such resources into a course. Furthermore, the appropriate care should be taken to ensure that they do not detract from cadaver-based learning activities.
5 Evaluating the Long-term Influences of the Laboratory Environment and a Computer-assisted Learning Resource on Anatomical Knowledge Retention

5.1 Chapter Introduction

The previous two chapters outlined the processes of (1) comparing dissection-based (DI) and prosection-based (PRO) laboratory environments (Chapter 3), and (2) creating and evaluating a computer-assisted learning (CAL) tool (Chapter 4) for their influences on learning outcomes such as subjective course experience, students’ approaches to learning, and academic performance. These studies provided helpful insights for the design and improvement of a laboratory-based course. Specifically, although students rated both DI and ‘enhanced’ PRO environments highly for their subjective course experience and had similar levels of academic performance, DI may have better promoted deep approaches to learning and skill development than PRO (Chapter 3). Furthermore, CAL itself may not have improved student learning in the course, but students who had high satisfaction with the CAL tool reported stronger tendencies toward deep approaches to learning (Section 4.3). Based on these findings and student feedback, new goals for improvement to the PRO cohort and amendments to the existing CAL resource have been identified to improve student learning in the laboratory.

However helpful to the progress of the program they may be, the previous two studies only examined short-term learning outcomes that shed limited insight into the success of the course at promoting lasting anatomical knowledge. This neglect of long-term outcomes has also been identified as a larger gap in the academic literature surrounding human anatomy education.
The following chapter highlights a study that aimed to strengthen the understanding of how different laboratory environments and learning resources in human anatomy affect students’ long-term academic success. Specifically, students’ anatomical knowledge recall ability was tested and compared between the DI and PRO populations. Furthermore, the influence of CAL resource use on knowledge recall ability was tested to determine if use of the self-directed learning tool helped or hindered long-term knowledge retention. While the results of this study provide important insights into how the program and its resources may influence long-term knowledge retention, it also identifies how the system may be improved to better foster lasting anatomical knowledge. Further research is needed to investigate other outcomes related to academic success, including career success and satisfaction.
5.2 Evaluating the Influences of the Laboratory Environment and Use of a Computer-assisted Learning Resource on Anatomical Knowledge Recall among Undergraduate University Students
5.2.1 Abstract

Developing persistent anatomical knowledge is important for students pursuing careers in the health sciences. The methods commonly employed to teach anatomy are constantly adapting to successfully achieve this goal, despite time and resource limitations. Popular interventions target changes to the laboratory environment such as moving from dissection- (DI) to prosection-based (PRO) teaching and adding supplemental computer-assisted learning (CAL) resources. This study evaluated the influences of both DI and PRO learning environments and the provision of a CAL resource on long-term knowledge recall among undergraduate human anatomy students at the University of Guelph. Participants reported their demographic information, approaches to learning (SAL), and CAL resource use through both online and written surveys. Knowledge retention was assessed using a combination of low- and high-order questions on written tests administered three months after the course, and performance was evaluated using the Structure of the Observed Learning Outcome taxonomy. Performance outcomes were compared between DI and PRO groups, as well as between low- and high-frequency CAL resource users. Multiple linear regression analyses were used to control for factors including SAL scores, final grades, and content familiarity. The laboratory environment did not directly influence knowledge recall ($p > 0.05$); however, high-frequency CAL resource users had stronger recall than low-frequency users ($p = 0.003$), and CAL resource use strongly influenced performance on high-order questions ($p = 0.014$). Deep approaches to learning were also positively associated with recall.
ability. Therefore, supplemental CAL resources should be used to support cadaver-based human anatomy education and promote long-term knowledge retention.

**Keywords**: gross anatomy education; undergraduate education; student approaches to learning; knowledge retention; cadaver dissection; computer-assisted learning; dissection-based anatomy; prosection-based anatomy

### 5.2.2 Introduction

Human anatomy is a fundamental subject of the health sciences and is critically important for students’ future success in most health-related careers. However, teaching anatomy requires considerable time and resources, which has led to marked reductions to gross anatomy education in medical curricula (Drake et al., 2009; Drake et al., 2014). These challenges have prompted various innovations aimed at maximizing the quality and efficiency of anatomy learning including adaptations to the learning environment and the incorporation of computer-assisted learning (CAL) resources (O’Flaherty and Phillips, 2015; Ghosh, 2017; Losco et al., 2017; Hew and Lo, 2018). Although the decline of gross human anatomy education appears to be slowing, medical education institutions remain burdened by limitations to the available time and resources (Drake et al., 2014). These limitations place an increased importance upon the anatomical knowledge students develop prior to beginning their advanced degrees. Accordingly, promoting long-term retention of anatomical knowledge is among the most desirable goals for undergraduate programs in the health sciences.
As a subject, human anatomy requires students to learn and retain a large amount of content. While students are typically able to amass sufficient knowledge to succeed on course assessments, the loss of that knowledge over time is of much higher concern for anatomy educators (Custers, 2010; Custers and Cate, 2011; Doomernik et al., 2017). Research on knowledge retention among undergraduate-level students is sparse; however, some studies on medical students suggest that up to 39% of previously learned material in the basic sciences is forgotten in the first year after testing (Custers, 2010; Kooloos et al., 2012; Doomernik et al., 2017) and up to 83% can be lost in the five years that follow (DuBois et al., 1969; Blunt and Blizard, 1975; Kennedy et al., 1981). Various factors have been shown to influence the rate and severity of this knowledge loss including sex (Doomernik et al., 2017), study strategies (Roediger and Karpicke, 2006; Karpicke and Blunt, 2011; Logan et al., 2011; Dirkx et al., 2014; Dobson and Linderholm, 2015a; Dobson and Linderholm, 2015b; Meyer et al., 2015; Dobson et al., 2017), and the degree of depth with which the students first learned the content (Onion and Slade, 1995; McManus et al., 1998; Ward and Walker, 2008; Dirkx et al., 2014). These factors coalesce as contributors to the students’ approaches to learning (SAL) (Biggs, 1987; Rubin et al., 2016; Dirkx et al., 2014). SAL is a framework that describes learning as the product of an interaction between the pre-existing personal characteristics of each student, the design of the learning environment, and how each student chooses to approach learning within that environment (Marton and Säljö, 1976; Biggs, 1987). According to this model, SAL is divided into contextual deep approach (DA) and surface approach (SA) scales that characterize the quality of the students’ interactions with the course material and learning
activities (Biggs, 1987). DAs to learning are associated with higher levels of engagement with the learning process and the active pursuit of a comprehensive and nuanced understanding of the topic, whereas SAs involve more superficial strategies such as rote memorization of only the necessary facts (Biggs, 1987). DAs to learning have been repeatedly associated with increases in knowledge recall ability among health sciences students (Onion and Slade, 1995; McManus et al., 1998; Ward and Walker, 2008; Dirkx et al., 2014). These ties imply that the structure of the learning environment can have a profound impact on the long-term retention of anatomical knowledge and therefore warrants strong consideration at all levels of education (Vaccarezza, 2018). This need is considerably pressing at undergraduate institutions, as they lay the foundational knowledge for students moving on to advanced degrees and careers in the health sciences.

In human anatomy education, an important element of typical course designs is the cadaver-based laboratory. Most institutions incorporate some form of cadaver-based education, commonly through either dissection- (DI) or prosection-based (PRO) environments. DI is traditionally favoured by most anatomy educators (Patel and Moxham, 2008); however, some consider PRO and other such alternative methods to be equally or even more proficient at supporting student learning (Nnodim, 1990; Topp, 2004; McLachlan, 2004; McLachlan et al., 2004; Brenton et al., 2007). Overall, the evidence suggests a stalemate – review of the research investigating the value of DI in comparison to non-DI approaches such as PRO has suggested that DI is no better or worse than other methodologies and non-DI designs do not hinder students’ academic
performance (Wilson et al., 2018). Some maintain that DI offers more nuanced advantages to learning such as the development of various transferrable skills (Ellis, 2001; Aziz et al., 2002; Granger, 2004; Lachman and Pawlina, 2006; Flack and Nicholson, 2018). Furthermore, findings from Chapter 3 indicated that participation in DI promoted DAs to learning and had positive associations with performance on skill-based assessments. Little to no research, however, has investigated the influence of these different laboratory environments on long-term anatomical knowledge retention. Accordingly, studies that evaluate students’ knowledge retention in anatomy have been suggested as an important next-step for anatomy education research (Wilson et al., 2018; Vaccarezza, 2018), especially when introducing changes to the traditional learning environment (Losco et al., 2017).

Since the creation and dissemination of digital resources has become more accessible, one popular amendment to learning environments in anatomy is the incorporation of CAL tools. While the appropriate (and inappropriate) contexts for their use are still unclear (Bergman, 2015; Vaccarezza, 2018), the evidence suggests that CAL resources can benefit learning in anatomy (Losco et al., 2017). These benefits appear to stem from students’ positive perceptions toward CAL tools (Glittenberg and Binder, 2006; Venkatiah, 2010; Codd and Choudhury, 2011; Hopkins et al., 2011; Stirling and Brit, 2014), which may play a role in SAL (Biggs, 1987). In fact, Section 4.3 demonstrated that although using the CAL resource more frequently did not correlate with deeper learning or academic performance, higher satisfaction with the tool was associated with higher DA to learning scores. While using DAs to learning has been repeatedly linked to stronger
knowledge retention (Onion and Slade, 1995; McManus et al., 1998; Ward and Walker, 2008; Dirkx et al., 2014), very few studies directly investigate the influence from CAL (Bloomfield et al., 2010; Fernández Alemán et al., 2011). More evidence is therefore required to establish whether CAL resource use can directly influence long-term knowledge retention, especially in anatomy.

To address these questions, the present study assessed the roles of the laboratory environment and supplemental CAL resources in the retention of anatomical knowledge. Specifically, student performance on a knowledge recall test (KRT) was examined for influences from their participation in DI and PRO and their individual use of the CAL resource while controlling for their contextual SAL. Based on the findings discussed in Chapter 3, it was expected that DI students would have higher KRT scores than PRO students. Furthermore, although CAL resource use was not correlated with SAL or performance in the course (Section 4.3), it was expected that students who used the resource more frequently would have better recall of the information covered in the course.

5.2.3 Methods

5.2.3.1 Subjects and Course Description

Two cohorts of students were analyzed for the present study; participants were recruited from the third-year undergraduate human anatomy course at the University of Guelph (UG) during the Fall semesters of 2015 and 2016. This course followed a regional approach to cover the regions of the back, upper limb, thorax, and abdomen in a high level of depth and detail. The remaining body regions were covered in a sister course,
which ran throughout the winter semester (not evaluated in this study). The course mainly included students enrolled in the HK and BIOM majors, but some students from the Biological Sciences (BIOS) major were also permitted to enroll with instructor consent, given available space. All of these majors share the same required courses except for a small number of elective courses and a half-credit introductory biomechanics course offered in the second year of the HK major. Each student was given the choice to enroll in either DI or PRO when they registered into the course. In total, 306 students (DI, \( n = 226 \); PRO, \( n = 80 \)) were enrolled in the human anatomy course during the Fall 2015 semester and 296 (DI, \( n = 235 \); PRO, \( n = 61 \)) were enrolled during the Fall 2016 semester. Although DI and PRO students attended separate laboratory sessions, they all attended the same lectures (three per week, 50 minutes each) and completed the same assessments.

The course used lectures to convey important information with traditional textbook images, as well as drawing activities, while the students used the laboratory to explore cadaveric specimens and learn the content in a hands-on environment. DI students were responsible for the dissection of one half (left or right) of a full-body cadaver in small groups of seven or eight. PRO students studied from those dissections in an ‘enhanced’ PRO environment (described in Chapter 3). Both DI and PRO cohorts also had access to professionally dissected specimens, osteological specimens, and paperback textbooks to use in the laboratory. The only difference in course design and administration between the Fall 2015 and 2016 cohorts was the addition of a CAL resource during the Fall 2016 semester (Appendices A – H). Fall 2016 students therefore had access to an additional
cadaver-based CAL resource that guided them through one important course concept from each unit (back, upper limb, thorax, and abdomen) (see Section 4.2 for a description of the content included in the CAL resource). Both cohorts completed the same course assessments which included two written tests (midterm and final; multiple choice and short answer questions), two laboratory tests (midterm and final; ‘bell-ringer’ identification and comprehension questions), a small-group presentation (two or three students from each group present a region), and weekly anatomical competency quizzes (discussions between the teaching assistants and each student group at the end of each laboratory session). The midterm examinations tested the back and upper limb units, while the thorax and abdomen units were evaluated on the final examinations.

This study was approved by the UG Research Ethics Board prior to data collection and all participants indicated informed consent before completing the study protocol.

5.2.3.2 Procedures

A combination of written and online surveys was used in this study. Specifically, participating students in both the Fall 2015 and Fall 2016 cohorts completed an online survey at the end of their respective semesters to report demographic information and answer questions pertaining to the course and its resources. In the Fall 2016 cohort only, participants completed weekly written surveys to quantify their CAL resource use. Students were offered a bonus grade of 1% on their final written examination for their participation in the online survey, or the option to instead complete a short assignment to achieve the grade. No additional incentive was offered for participation in the weekly written surveys.
Three months after the completion of both the Fall 2015 and Fall 2016 semesters, students were invited to participate in a study to evaluate their retention of anatomical knowledge and offered complimentary food and beverages for their attendance. After providing informed written consent, the participants were randomly assigned a four-question KRT on content from either the back, upper limb, thorax, or abdomen (see Section 4.2.3.4 for a description of the test design). The students were given up to one hour to complete the test. After they completed the KRT, students submitted their answers to a research assistant for grading (see Section 4.2.3.4 for a description of the grading criteria).

5.2.3.3 Surveys

The online survey was available for 10 days between the final class and the final exam. Participating students were asked to report their demographic information including age, sex, and program of study, and also to complete the Revised Two-factor Study Process Questionnaire (R-SPQ-2F) to yield their contextual SAL scores (Biggs et al., 2001). The R-SPQ-2F uses 20 five-point Likert-type questions to measure SAL on ‘deep’ and ‘surface’ scales based on how closely each student identified with statements corresponding to their learning motives and study strategies (Biggs et al., 2001). Ratings on items that align with DAs and SAs to learning are combined to yield a DA score and a SA score for each student, each with minimum possible scores of 10 and maximum possible scores of 50 (Biggs et al., 2001). Higher scores on a given learning approach are indicative of a student’s tendency to use that approach during their studies (Biggs et al., 2001). SAL scores were analyzed in Chapter 3 and Section 4.3 for influences from
the students’ demographic characteristics and their perceptions of the learning environment (Biggs et al, 2001). In the present study, these factors were considered as contributors to the students’ contextual DA and SA scores and therefore excluded from the analyses (Wang et al., 2013).

The weekly written surveys asked students to indicate whether they had used the CAL resource during that laboratory session. Each week of laboratories corresponded to a specific unit (or region of the body) that was being covered in the course at that time. A KRT-specific CAL resource use variable (expressed as a percentage) was therefore created to represent the number of times the student accessed the CAL resource during the weeks that covered the content tested in the KRT they received, divided by the total number of weeks that content was available. For example, if a student who completed the upper limb KRT accessed the CAL resource three times during the six weeks that covered midterm-related material (back and upper limb units), their KRT-specific CAL resource use value would be 50%. Low-frequency CAL resource users were defined as those who had a KRT-specific CAL resource use frequency below 50%, while all others were considered high-frequency users. The surveys included an additional question regarding the students’ perceived usefulness of the tool (described in Section 4.3); however, those responses were not analyzed for this study.

5.2.3.4 Knowledge Recall Tests

Recall of content covered in the Fall 2015 and 2016 semesters (back, upper limb, thorax, and abdomen) was evaluated using KRTs designed to align with the assessment style and level of detail encountered in the course. Four separate tests were created
(one per unit) and each included a combination of low- and high-order questions according to criteria outlined by the Blooming Anatomy Tool (BAT; see *The Blooming Anatomy Tool*, below) (Thompson and O’Loughlin, 2015). Within each of the four KRTs, two relevant anatomical concepts were evaluated. Specifically, for each unit, the topic that was covered in the CAL resource (CAL resource concept) and one other topic from that region (non-CAL resource concept) were tested using one low- and one high-order question. Each test therefore consisted of four short-answer questions: (1) low-order CAL resource concept question, (2) high-order CAL resource concept question, (3) low-order non-CAL resource concept question, (4) high-order non-CAL resource question. Since all CAL resource concepts were included in the KRTs (see Section 4.2 for a summary of CAL resource concepts), non-CAL resource concepts were chosen based on their complexity, emphasis within the course, and independence from the CAL resource concepts. For instance, if the CAL resource concept for a region focused on the nervous system, the non-CAL resource concept included in the KRT for that region would have featured a different system (i.e., cardiovascular, musculoskeletal).

The short-answer questions included in the KRTs followed an open format to give students the freedom to demonstrate their fullest understanding of the content and open the opportunity for a broad distribution of response quality (Newton and Martin, 2013). To ensure that the questions presented similar levels of difficulty between concepts and regions, informal pilot studies were performed using volunteers from the fourth-year Advanced Human Anatomy course at UG. These volunteers were asked to answer each question and rate its difficulty on a five-point Likert scale. Questions that were deemed
too easy or too difficult were removed or adapted, then re-tested with new participants until there were no statistically significant differences in performance or difficulty scores between questions in different concepts or units. The questions included in the final versions of the KRTs are outlined in Table 5.1.
### Table 5.1: Summary of knowledge retention test questions

<table>
<thead>
<tr>
<th>Unit</th>
<th>CAL Concept</th>
<th>BAT Level</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back</td>
<td>Yes</td>
<td>Level 2 (Low)</td>
<td>Describe and/or draw the motor and sensory components of a typical spinal nerve. Begin at the spinal cord and end with the anterior/posterior rami and their peripheral target areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 4 (High)</td>
<td>A stabbing victim has suffered a completely severed posterior ramus. Describe the functional implications of her injury. How do these implications differ in the case of a completely severed posterior root?</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>Level 2 (Low)</td>
<td>Describe the organization of muscles and muscle groups in the back region (i.e., superficial to deep).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 3 (High)</td>
<td>A patient has suffered a crushed C5 vertebra in a car accident, completely severing his spinal cord at that level. Describe any changes in upper limb function that may result from his injury.</td>
</tr>
<tr>
<td>Upper Limb</td>
<td>Yes</td>
<td>Level 2 (Low)</td>
<td>Draw and/or describe the brachial plexus and its major branches.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 4 (High)</td>
<td>A patient has suffered a crushed C5 vertebra in a car accident, completely severing his spinal cord at that level. Describe any changes in upper limb function that may result from his injury.</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>Level 2 (Low)</td>
<td>Draw and label the major arteries the upper limb from the shoulder to the hand. Include all branches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 3 (High)</td>
<td>A patient has suffered a blood clot that has completely occluded the brachial artery within the cubital fossa. Describe a potential route for blood flow to the hand in this scenario.</td>
</tr>
<tr>
<td>Thorax</td>
<td>Yes</td>
<td>Level 2 (Low)</td>
<td>Draw and/or describe the pathways of blood supply to the heart. Be sure to include specific arterial branches.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 3 (High)</td>
<td>A patient has presented with a coronary artery blockage that requires bypass surgery. The doctor opts to use the patient's left internal thoracic artery for the bypass. Describe the outcome this will have on the blood supply to the patient's diaphragm.</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>Level 2 (Low)</td>
<td>Describe and/or draw the organization of the thoracic mediastina. Include all important structures, borders, and references to relevant positional landmarks.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 4 (High)</td>
<td>During your final exam, your friend caught you cheating off of her paper. Your friend decided to take the law into her own hands by stabbing you in the chest with her super-strong pencil. You suffered a deep wound near the midline of your chest between the body of your sternum and your manubrium. What structures within the thorax are likely to be affected? Describe any functional impairments you may experience as a result of your injury.</td>
</tr>
<tr>
<td>Abdomen</td>
<td>Yes</td>
<td>Level 2 (Low)</td>
<td>Describe and/or draw the major arteries that supply the abdominal viscera.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 3 (High)</td>
<td>A patient presents with a completely occluded inferior mesenteric artery. Would the patient's distal colon receive any oxygenated blood? Explain.</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>Level 2 (Low)</td>
<td>Explain the organization of the anterolateral abdominal wall layers (i.e., superficial to deep), approximately 5 cm superior to the anterior superior iliac spine.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 4 (High)</td>
<td>A 14-year-old boy presents with pain in his inguinal region after competing in a weightlifting competition. A medical inspection revealed that he has suffered a hernia. Based on your knowledge of the layers of the abdominal wall and spermatic cord coverings, (1) indicate the type of hernia the boy has likely experienced, (2) determine the most likely cause of the hernia, and (3) describe the route taken by the herniated intestines. Be sure to reference all important anatomical landmarks.</td>
</tr>
</tbody>
</table>
The Blooming Anatomy Tool

The BAT is an adaptation of Bloom’s Taxonomy of Educational Objectives for use specifically in anatomy (Bloom, 1956; Anderson et al., 2001). The BAT uses discipline-specific language and anatomy-related examples to act as a framework for ranking the cognitive complexity of examination questions. The levels included in the BAT include: ‘knowledge’, ‘comprehension’, ‘application’, and ‘analysis’. According to this tool, questions that fall under levels one and two are considered to be ‘lower-order’, while those in levels three and four are termed ‘higher-order’. Lower-order questions are defined as straightforward, likely to be found in the students’ notes or textbook, and usually not placed in a clinical context (Thompson and O’Loughlin, 2015). Conversely, higher-order questions ask students to interpret and make independent connections from the information, which is presented in a clinical or novel scenario (Thompson and O’Loughlin, 2015). Questions used in the KRTs were evaluated independently by several research assistants using the BAT. When discrepancies in ratings between research assistants were encountered, the ratings were discussed until a consensus was met. The final BAT ratings for each question are outlined in Table 5.1.

Knowledge Recall Test Grading

After students completed the questions and submitted their KRT, they were graded according to the Structure of Observed Learning Outcomes (SOLO) taxonomy (Biggs and Collis, 1982). The SOLO taxonomy is a measurement tool used to describe and evaluate the degree of complexity in a student’s understanding of a topic through categories that include (from lowest to highest quality): ‘prestructural’, ‘unistructural’, ‘multistructural’,

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‘relational’, and ‘extended abstract’ (Biggs and Collis, 1982). The lower categories are typically associated with SAs to learning, while the higher ‘relational’ and ‘extended abstract’ levels align with DAs to learning (Hazel et al., 2002; Hattie and Brown, 2004; Newton and Martin, 2013). Table 5.2 presents a summary of the criteria associated with each category of SOLO taxonomy for this study.

Table 5.2: Summary of Structure of the Observed Learning Outcome taxonomy categories and their associated evaluation criteria

<table>
<thead>
<tr>
<th>SOLO Category</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prestructural</td>
<td>• No relevant structures are included</td>
</tr>
<tr>
<td></td>
<td>• Knowledge of structures or their organization is not demonstrated</td>
</tr>
<tr>
<td>Unistructural</td>
<td>• Some relevant components are included</td>
</tr>
<tr>
<td></td>
<td>• Most of the structures and their organization are omitted or not understood</td>
</tr>
<tr>
<td>Multistructural</td>
<td>• All or most relevant structures are included</td>
</tr>
<tr>
<td></td>
<td>• Complex relationships between the different structures and their significance are missing or incorrect</td>
</tr>
<tr>
<td>Relational</td>
<td>• All or most relevant structures are included</td>
</tr>
<tr>
<td></td>
<td>• The different structures are organized together as a complex system and their significance is understood</td>
</tr>
<tr>
<td>Extended Abstract</td>
<td>• All relevant structures are included</td>
</tr>
<tr>
<td></td>
<td>• Relationships between structures are properly understood and have been applied in a context beyond that stated in the question</td>
</tr>
</tbody>
</table>

Note. Adapted from Biggs and Collis (1982).

Each KRT was graded separately by two research assistants using the SOLO taxonomy categories and evaluation criteria outlined in Table 5.2. The reliability of classifications was then compared, and any discrepancies were discussed between the two researchers until a single classification level was agreed upon. Therefore, participants received a grade out of five for each individual KRT question that was later converted to a percentage for analysis.
5.2.3.5 Statistical Analyses

Only students who completed all of the research surveys in addition to the KRT were included in the analyses. For comparisons between DI and PRO, the Fall 2015 and Fall 2016 populations were combined; however, since the CAL resource was available exclusively during the Fall 2016 semester, only those students were used when examining the impact of CAL use on knowledge retention. Therefore, results from the DI versus PRO comparisons and the influence of the CAL resource on knowledge retention are presented separately.

All data were compiled using Microsoft Excel 2016 and statistical analyses were performed using IBM SPSS Statistics software version 25. Normality was assessed using the Shapiro-Wilk test where appropriate. Significance for all tests was declared at \( p \leq 0.05 \). All data summaries include the mean \( (M) \) and standard error of the mean \( (SEM) \) unless otherwise stated.

Comparing Laboratory Environments

For the combined Fall 2015 and 2016 study populations, demographic variables were first compared between DI and PRO cohorts to detect any major differences in participation. Mean age was compared between DI and PRO with the Mann-Whitney U test for non-parametric data. Sex and program distributions were compared using the chi-squared and Fisher’s exact tests of independence, respectively. Demographic variables such as these were considered as elements of the participants’ SAL scores and were therefore excluded from further analyses where DA and SA were used instead (Wang et al., 2013). SAL data were obtained via the R-SPQ-2F, then DA and SA scores were
calculated according to Biggs and colleagues (2001) for the studies described in Chapter 3 and Section 4.3. In the present study, these scores were compared between the DI and PRO populations using independent-samples \( t \)-tests. Final course grades were collected for use as a control variable that represented each student’s previous understanding of human anatomy when analyzing KRT scores (Theobald and Freeman, 2014). These grades were compared between DI and PRO students using the Mann-Whitney U test for non-parametric data.

Overall KRT scores were compared between the DI and PRO populations with the Mann-Whitney U test for non-parametric data. Next, a multiple linear regression (MLR) model was run to predict overall KRT scores from several potential explanatory variables. MLR analyses show which variables significantly contribute to the explanation of individual KRT scores and which do not. The variables included in the MLRs for this study were: (1) student cohort, to control for differences that may have arisen between the Fall 2015 and 2016 academic semesters, (2) DA and SA scores, to represent SAL in the human anatomy course, (3) final grades, as a control for student aptitude (Theobald and Freeman, 2014), (4) laboratory environment, to quantify the effect of participation in DI or PRO laboratories on knowledge retention, and (5) KRT region familiarity, a variable created to control for how recently the students learned the content that they were tested on in the KRT they received. This ‘familiarity’ control was a categorical variable in which students who received KRTs on the back and upper limb (content covered on the midterm examinations) were coded ‘0’ and students who completed KRTs on the thorax and
abdomen (content covered on the final examinations) were coded ‘1’ to reflect the recency with which they had studied the material for the course.

To determine if there were any differences between DI and PRO students in performance on low- and high-order questions, separate knowledge retention scores were calculated using the questions that aligned those cognitive levels (see Table 5.1). These scores were directly compared between DI and PRO students using the Mann-Whitney U test. To control for potential mitigating variables, separate MLR analyses were also performed to predict performance on low- and high-order questions using the same list of variables as presented above.

*Influence of Computer-assisted Learning Resource Use*

For this section of the analyses only participants from the Fall 2016 cohort were used, since that was the only cohort to have access to the CAL resource. For the initial demographic comparisons, participating students were categorized as either low- or high-frequency CAL users based on their KRT-specific CAL resource use frequency. Mean age was compared between low- and high-frequency users with the Mann-Whitney U test for non-parametric data and the chi-squared test of independence was used to evaluate sex, program, and laboratory enrollment distributions. These demographic variables were considered as manifested in the participants’ SAL scores and were therefore represented in the MLR analyses by the contextual DA and SA scores (Wang et al., 2013). The DA and SA scores were compared between the low- and high-frequency user groups using independent-samples t-tests, and final course grades were compared between DI and PRO students using the Mann-Whitney U test.
Direct comparisons of various KRT performance measures were then made between low- and high-frequency CAL users. Overall KRT scores and performance on low- and high-order questions were compared between the two groups using the Mann-Whitney U test. Performance on CAL concept questions and non-CAL concept questions were also considered. CAL concept scores were calculated by combining students’ KRT grades on questions that were covered in the CAL resource, while non-CAL concept scores were calculated by combining the remaining questions (CAL concept and non-CAL concept questions are outlined in Table 5.1). These scores were then compared between low- and high-frequency CAL resource users with the Mann-Whitney U test.

MLR analyses were used to determine the influence of CAL resource use on anatomical knowledge retention while controlling for various potentially confounding factors. These factors included laboratory environment (DI or PRO), contextual DA and SA scores, final grades, and KRT region familiarity (described above). The KRT-specific CAL resource use variable served as the test variable in each MLR model. The first MLR examined correlations between these variables and overall KRT scores, then scores on low- and high-order questions were each examined as the dependent variable in separate MLRs.

5.2.4 Results

5.2.4.1 Comparing Learning Environments

Demographic Profiles, Student Approach to Learning, and Final Grades

In total, 87 students (DI, n = 68; PRO, n = 19) from Fall 2015 and 104 students (DI, n = 80; PRO, n = 24) from Fall 2016 participated in all aspects of the study. These
numbers resulted in a combined study population of 148 DI students and 43 PRO students. Demographic information for the combined DI and PRO populations is summarized in Table 5.3. These populations had similar distributions of sex, and program of study (Table 5.3); however, mean age was found to be statistically different between DI (20.20 ± 0.08) and PRO (20.84 ± 0.33) students (p < 0.0005). No other statistically significant differences in demographic factors were detected between the DI and PRO study populations at p ≤ 0.05. In the comparisons of SAL scores, mean DA and SA scores were not statistically significantly different between DI and PRO groups (Table 5.3). Finally, comparisons of final grades between DI and PRO populations did not find statistically significantly differences at the 5% level (p = 0.055).

Table 5.3: Summary of demographic profiles, student approaches to learning, and final grades of students enrolled in the dissection- and prosection-based laboratories during the Fall 2015 and 2016 semesters (combined) of the human anatomy course at the University of Guelph

<table>
<thead>
<tr>
<th>Laboratory Environment</th>
<th>Dissection</th>
<th>Prosection</th>
<th>p</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Number</strong></td>
<td>148</td>
<td>43</td>
<td></td>
<td>191</td>
</tr>
<tr>
<td><strong>Age (M ± SD; years)</strong></td>
<td>20.20 ± 0.92</td>
<td>20.84 ± 2.15</td>
<td>&lt; 0.0005*</td>
<td>20.35 ± 1.32</td>
</tr>
<tr>
<td><strong>Sex (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>27.0</td>
<td>14.0</td>
<td>0.078</td>
<td>24.1</td>
</tr>
<tr>
<td>Female</td>
<td>73.0</td>
<td>86.0</td>
<td></td>
<td>75.9</td>
</tr>
<tr>
<td><strong>Program of Study (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Kinetics</td>
<td>52.0</td>
<td>51.2</td>
<td>&gt; 0.999</td>
<td>51.8</td>
</tr>
<tr>
<td>Biomedical Sciences</td>
<td>45.3</td>
<td>46.5</td>
<td></td>
<td>45.6</td>
</tr>
<tr>
<td>Other</td>
<td>2.7</td>
<td>2.3</td>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td><strong>Contextual DA Score (M ± SD)</strong></td>
<td>34.69 ± 6.34</td>
<td>33.09 ± 6.06</td>
<td>0.144</td>
<td>34.33 ± 6.30</td>
</tr>
<tr>
<td><strong>Contextual SA Score (M ± SD)</strong></td>
<td>23.86 ± 6.13</td>
<td>23.30 ± 5.71</td>
<td>0.591</td>
<td>23.74 ± 6.03</td>
</tr>
<tr>
<td><strong>Final Course Grade (M ± SD; %)</strong></td>
<td>89.82 ± 6.11</td>
<td>87.57 ± 7.01</td>
<td>0.055</td>
<td>89.31 ± 6.38</td>
</tr>
</tbody>
</table>

**Note.** The asterisk (*) denotes significance at p ≤ 0.05.

**Knowledge Recall**

Overall KRT performance did not significantly differ between DI (49.73% ± 0.85) and PRO (47.79% ± 1.53) groups in a direct comparison (p = 0.241).
Table 5.4 displays the results of the MLR analysis run to detect the influence of the laboratory environment on overall KRT performance while controlling for other potential explanatory variables \([F(6,190) = 8.179, p < 0.0005, R^2 = 0.211]\). The model found that DA score \((p = 0.012)\), final grade \((p < 0.0005)\), and region familiarity \((p = 0.001)\) were all significant positive predictors of KRT score; however, KRT score was not significantly correlated with SA scores \((p = 0.924)\), academic cohort \((p = 0.138)\), or participation in either DI or PRO \((p = 0.994)\) (Table 5.4).

### Table 5.4: Multiple linear regression analyses of the influences of participation in a prosection- or dissection-based laboratory on overall anatomical knowledge retention

<table>
<thead>
<tr>
<th>Variable</th>
<th>(B)</th>
<th>(SE_B)</th>
<th>(B')</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Intercept</td>
<td>-11.408</td>
<td>11.024</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cohort (Fall 2016)</td>
<td>-2.122</td>
<td>1.423</td>
<td>-0.103</td>
<td>0.138</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.293</td>
<td>0.116</td>
<td>0.180</td>
<td>0.012*</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>-0.012</td>
<td>0.120</td>
<td>-0.007</td>
<td>0.924</td>
</tr>
<tr>
<td>Final Grade</td>
<td>0.559</td>
<td>0.111</td>
<td>0.347</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>KRT Region Familiarity (Final Examination Content)</td>
<td>4.607</td>
<td>1.363</td>
<td>0.224</td>
<td>0.001*</td>
</tr>
<tr>
<td>Laboratory Environment (Dissection)</td>
<td>0.012</td>
<td>1.642</td>
<td>&lt; 0.001</td>
<td>0.994</td>
</tr>
</tbody>
</table>

**Note.** The reference levels for the cohort and laboratory environment variables are Fall 2015 and prosection, respectively. The reference level for KRT region familiarity is midterm examination content. \(B\) = unstandardized regression coefficient; \(SE_B\) = standard error of the coefficient; \(B'\) = standardized coefficient; \(p\) = statistical significance of \(B'\); asterisks (*) denote significance at \(p \leq 0.05\).

In a direct comparison of performance on low-order questions, no statistically significant difference was detected between DI \((54.39\% \pm 1.01)\) and PRO \((51.40\% \pm 2.09)\) students \((p = 0.340)\). Similarly, performance on high-order questions was not significantly different between DI \((45.07\% \pm 1.05)\) and PRO \((44.19\% \pm 1.92)\) students \((p = 0.748)\).

The MLR analysis on low-order questions \([F(6,190) = 5.145, p < 0.0005, R^2 = 0.144]\), revealed that final course grades were the only statistically significant predictor of performance \((p < 0.0005)\). All other variables, including laboratory environment \((p = 0.994)\),
0.598), were not significantly correlated with performance on low-order questions. The correlation coefficients and significance values for all variables are available in Table 5.5a. In the MLR for high-order questions \( F(6,190) = 5.880, p < 0.0005, R^2 = 0.161 \), DA score \( p = 0.022 \), final course grades \( p = 0.001 \), and region familiarity \( p < 0.0005 \) were all statistically significant positive predictors of performance, while laboratory environment \( p = 0.604 \) and all other included variables were not (Table 5.5b).

### Table 5.5: Multiple linear regression analyses of the influences of participation in a prosection- or dissection-based laboratory on performance on (a) low- and (b) high-order knowledge retention test questions

<table>
<thead>
<tr>
<th>Variable</th>
<th>( B )</th>
<th>( SE_B )</th>
<th>( B' )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Low-order Questions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge Retention Score (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>-10.035</td>
<td>14.095</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohort (Fall 2016)</td>
<td>-2.259</td>
<td>1.820</td>
<td>-0.089</td>
<td>0.216</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.247</td>
<td>0.148</td>
<td>0.124</td>
<td>0.096</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>-0.072</td>
<td>0.154</td>
<td>-0.035</td>
<td>0.639</td>
</tr>
<tr>
<td>Final Grade</td>
<td>0.632</td>
<td>0.143</td>
<td>0.319</td>
<td></td>
</tr>
<tr>
<td>KRT Region Familiarity (Final Examination Content)</td>
<td>2.005</td>
<td>1.743</td>
<td>0.080</td>
<td>0.251</td>
</tr>
<tr>
<td>Laboratory Environment (Dissection)</td>
<td>1.109</td>
<td>2.100</td>
<td>0.037</td>
<td>0.598</td>
</tr>
<tr>
<td><strong>b. High-order Questions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge Retention Score (dependent)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Intercept</td>
<td>-12.780</td>
<td>14.024</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohort (Fall 2016)</td>
<td>-1.985</td>
<td>1.811</td>
<td>-0.078</td>
<td>0.274</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.338</td>
<td>0.147</td>
<td>0.168</td>
<td>0.022*</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>0.049</td>
<td>0.153</td>
<td>0.023</td>
<td>0.748</td>
</tr>
<tr>
<td>Final Grade</td>
<td>0.486</td>
<td>0.142</td>
<td>0.244</td>
<td>0.001*</td>
</tr>
<tr>
<td>KRT Region Familiarity (Final Examination Content)</td>
<td>7.208</td>
<td>1.734</td>
<td>0.284</td>
<td>&lt; 0.0005*</td>
</tr>
<tr>
<td>Laboratory Environment (Dissection)</td>
<td>-1.085</td>
<td>2.089</td>
<td>-0.036</td>
<td>0.604</td>
</tr>
</tbody>
</table>

**Note.** The reference levels for the cohort and laboratory environment variables are Fall 2015 and prosection, respectively. The reference level for KRT region familiarity is midterm examination content. \( B \) = unstandardized regression coefficient; \( SE_B \) = standard error of the coefficient; \( B' \) = standardized coefficient; \( p \) = statistical significance of \( B' \); asterisks (*) denote significance at \( p \leq 0.05 \).
5.2.4.2 Influence of Computer-assisted Learning Resource Use

Demographic Profiles, Student Approach to Learning, and Final Grades

In the demographic comparisons of low- and high-frequency user groups, none of the variables were statistically significantly different. However, although SA scores were not significantly different between the groups, high-frequency users (35.60 ± 1.01) had significantly higher DA scores than low-frequency users (31.98 ± 0.725, \( p = 0.003 \)). No significant difference in final grades was detected between low- and high-frequency users. See Table 5.6 for demographic characteristics, mean SAL scores, and mean final grades of both groups.

Table 5.6: Summary of demographic profiles, students’ approaches to learning, and final grades of low- and high-frequency users of the computer-assisted learning resource during the Fall 2016 semester of the human anatomy course at the University of Guelph

<table>
<thead>
<tr>
<th>CAL Resource Use Frequency</th>
<th>Low</th>
<th>High</th>
<th>( p )</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number</td>
<td>61</td>
<td>43</td>
<td></td>
<td>104</td>
</tr>
<tr>
<td>Laboratory Environment (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dissection</td>
<td>78.7</td>
<td>74.4</td>
<td>0.611</td>
<td>76.9</td>
</tr>
<tr>
<td>Prosection</td>
<td>21.3</td>
<td>25.6</td>
<td></td>
<td>23.1</td>
</tr>
<tr>
<td>Age (( M \pm SD ); years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.25 ± 1.18</td>
<td>20.67 ± 2.27</td>
<td>0.239</td>
<td>20.42 ± 1.72</td>
<td></td>
</tr>
<tr>
<td>Sex (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>31.1</td>
<td>27.9</td>
<td>0.722</td>
<td>29.8</td>
</tr>
<tr>
<td>Female</td>
<td>68.9</td>
<td>72.1</td>
<td></td>
<td>70.2</td>
</tr>
<tr>
<td>Program of Study (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Kinetics</td>
<td>52.5</td>
<td>48.8</td>
<td>0.716</td>
<td>51.0</td>
</tr>
<tr>
<td>Biomedical Sciences</td>
<td>47.5</td>
<td>51.2</td>
<td></td>
<td>49.0</td>
</tr>
<tr>
<td>Contextual DA Score (( M \pm SD ))</td>
<td>31.98 ± 5.66</td>
<td>35.60 ± 6.62</td>
<td>0.003*</td>
<td>33.48 ± 6.31</td>
</tr>
<tr>
<td>Contextual SA Score (( M \pm SD ))</td>
<td>24.72 ± 5.60</td>
<td>24.74 ± 6.92</td>
<td>0.985</td>
<td>24.73 ± 6.14</td>
</tr>
<tr>
<td>Final Course Grade (( M \pm SD ); %)</td>
<td>90.07 ± 6.00</td>
<td>91.20 ± 4.96</td>
<td>0.306</td>
<td>90.54 ± 5.59</td>
</tr>
</tbody>
</table>

Note. The asterisk (*) denotes significance at \( p \leq 0.05 \).

Knowledge Recall

Comparisons of overall KRT scores between low- and high-frequency CAL resource users revealed that high-frequency CAL resource users (52.33% ± 1.65) performed significantly better than low-frequency CAL resource users (46.23% ± 1.25, \( p \)}
This trend continued when the overall KRT scores were broken into CAL resource concept and non-CAL resource concept questions. High-frequency CAL resource users (54.19% ± 2.24) demonstrated significantly higher performance than low-frequency users (48.03% ± 1.67) on CAL concept KRT questions \((p = 0.031)\). Furthermore, high-frequency CAL resource users (50.47% ± 1.76) significantly out-performed low-frequency CAL resource users (44.43% ± 1.45) on non-CAL resource questions by approximately 6% \((p = 0.009)\).

Table 5.7 displays the results of a MLR analysis run to predict overall KRT performance \([F(6,103) = 5.113, p < 0.0005, R^2 = 0.240]\). DA score \((p = 0.043)\), final grade \((p = 0.006)\), and KRT region familiarity \((p = 0.007)\) were all found to be significant positive predictors of overall KRT score. Overall KRT score was not significantly correlated with KRT-specific CAL resource use at \(p \leq 0.05\), but it did demonstrate a positive trend \((p = 0.077)\) (Table 5.7).

**Table 5.7: Multiple linear regression analyses of the influences of computer-assisted learning resource use on overall anatomical knowledge retention**

<table>
<thead>
<tr>
<th>Variable</th>
<th>(B)</th>
<th>(SE_B)</th>
<th>(B')</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Intercept</td>
<td>-15.001</td>
<td>17.188</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laboratory Environment (Dissection)</td>
<td>0.983</td>
<td>2.255</td>
<td>0.039</td>
<td>0.664</td>
</tr>
<tr>
<td>Contextual Deep Approach Score</td>
<td>0.338</td>
<td>0.165</td>
<td>0.201</td>
<td>0.043*</td>
</tr>
<tr>
<td>Contextual Surface Approach Score</td>
<td>0.056</td>
<td>0.164</td>
<td>0.033</td>
<td>0.733</td>
</tr>
<tr>
<td>Final Grade</td>
<td>0.498</td>
<td>0.176</td>
<td>0.263</td>
<td>0.006*</td>
</tr>
<tr>
<td>KRT Region Familiarity (Final Examination Content)</td>
<td>5.462</td>
<td>1.971</td>
<td>0.258</td>
<td>0.007*</td>
</tr>
<tr>
<td>KRT-specific CAL Resource Use</td>
<td>0.069</td>
<td>0.038</td>
<td>0.165</td>
<td>0.077</td>
</tr>
</tbody>
</table>

*Note.* The reference levels for the laboratory environment and KRT region familiarity variables are prosection and midterm examination content, respectively. \(B\) = unstandardized regression coefficient; \(SE_B\) = standard error of the coefficient; \(B'\) = standardized coefficient; \(p\) = statistical significance of \(B'\); asterisks (*) denote significance at \(p \leq 0.05\).
In direct comparisons of performance on low- and high-order questions, high-frequency CAL resource users (56.28% ± 1.82) were found to have significantly better scores on low-order KRT questions than low-frequency users (50.98% ± 1.56, \( p = 0.038 \)). Similarly, high-frequency CAL resource users (48.37% ± 2.05) performed significantly better than low-frequency CAL resource users (41.48% ± 1.68) on high-order KRT questions (\( p = 0.017 \)).

In the MLR analysis of low-order questions [\( F(6,103) = 2.076, \ p = 0.063, \ R^2 = 0.114 \)], DA score was the only significant predictor of knowledge retention (\( p = 0.038 \)); KRT-specific CAL resource use did not significantly contribute to the prediction (\( p = 0.772 \)). Correlation coefficients and significance values are summarized in Table 5.8a. The results of the MLR run to predict scores on high-order KRT questions [\( F(6,103) = 5.070, \ p < 0.0005, \ R^2 = 0.239 \)] are presented in Table 5.8b. Aside from the control variables, final grade (\( p = 0.009 \)) and KRT region familiarity (\( p = 0.012 \)), KRT-specific CAL resource use was the only statistically significant predictor for performance on high-order knowledge retention questions (\( p = 0.014 \)) (Table 5.8b).
### 5.2.5 Discussion

The goals of this study were to examine the roles of the DI and PRO human anatomy laboratory environments and the students’ use of a novel CAL resource on their retention of anatomical knowledge after three months. By evaluating the relationships between students’ approaches to learning, laboratory enrollment, CAL resource use, and proficiency at anatomical knowledge recall, this study determined that the laboratory environment had no direct effect on anatomical knowledge retention. However, students who used the curriculum-targeted CAL resource more frequently had better performance on high-order KRT questions. These findings contribute to ongoing discussions...
surrounding DI and PRO laboratory environments and CAL resources in human anatomy education and indicate that the provision of additional study resources may be beneficial to student learning in the anatomical sciences.

The role of the laboratory environment in the successful learning of human anatomy has garnered widespread debate over the past several decades in anatomy education research, specifically surrounding DI and PRO (Nnodim, 1990; Nnodim et al., 1996; Yeager, 1996; Dinsmore et al., 1999; Aziz et al., 2002; Granger, 2004; McLachlan, 2004; McLachlan et al., 2004; Older, 2004; Pawlina and Lachman, 2004; Topp, 2004; Ghosh, 2017). While research into SAL in DI and PRO environments is limited, DI is typically heralded as the approach that best facilitates traits associated with DA to learning such as the development of transferable skills (Ellis, 2001; Aziz et al., 2002; Granger, 2004; Patel and Moxham, 2006; Kerby et al., 2011; Davis et al., 2014; Bouwer et al., 2016; Rehkämper, 2016). Furthermore, the findings presented in Chapter 3 demonstrated that participation in DI was associated with higher DA scores and better performance on skill-based assessments. Based on those findings and published associations between DAs to learning and knowledge retention (Onion and Slade, 1995; McManus et al., 1998; Ward and Walker, 2008; Dirkx et al., 2014), it was expected that DI students would perform better on KRTs than PRO students. However, no significant associations were detected directly between laboratory enrollment and KRT performance in this study. Instead, the MLR analyses determined that DAs to learning, final grades, and the recency with which the content was studied were more strongly associated with knowledge retention. These findings may be interpreted in a number of ways. For
instance, those who endorse alternative teaching approaches may view this as evidence that standard PRO can support knowledge retention just as well as DI, and can therefore offer a feasible, cheaper, and more efficient alternative laboratory environment (Nnodim, 1990; McLachlan et al., 2004; Topp, 2004; Brenton et al., 2007). However, the findings more likely reflect the ability of MLR analyses to jointly consider all the potential explanatory variables together and identify the strongest drivers behind an observed effect (Theobald and Freeman, 2014). Because the laboratory environment variable was accompanied in the MLRs by other mitigating variables, namely contextual DA score, it is possible that stronger relationships between these variables and KRT scores nullified any latent correlations between KRT scores and the laboratory environment. However, since DI has been shown to promote DAs to learning (Chapter 3) and DA to learning was a significant predictor of knowledge retention in this study (Tables 5.4 and 5.5b), DI may better support lasting learning than PRO through that pathway. Regardless, the associations between DA scores and knowledge retention demonstrate that any approach (not limited to DI or PRO) that promotes DA to learning should be endorsed at the undergraduate level to better prepare students for their future academic pursuits.

Considering the effect that the learning environment and its associated resources can have on SAL (Biggs, 1987), it is equally as important to evaluate newly introduced resources as it is to examine the laboratory environment. Building upon the research conducted in Section 4.3, this study continued the evaluation of a novel CAL resource intervention by exploring its role in anatomical knowledge retention. Section 4.3 revealed that using the CAL resource had no influence on SAL or performance, and its inclusion in
the course may have even influenced the students away from DAs and toward SAs to learning. Despite those findings, it was expected that increased exposure to curriculum-relevant content through higher-frequency use of the CAL resource would help students to internalize the content and retain it more strongly than those who used the resource more sparingly or not at all. This hypothesis was confirmed to a degree, in that high-frequency CAL users performed significantly better than low-frequency CAL users on all measures of knowledge retention in this study, including questions that targeted concepts not covered in the CAL resource. Furthermore, MLR analyses revealed a positive trend between overall KRT scores and CAL resource use (Table 5.7) and showed that CAL resource use was a significant contributor to performance on high-order KRT questions (Table 5.8b), despite controlling for other potential mitigating factors including students’ individual performance in the course. In addition, since high-frequency CAL users had significantly higher DA scores than low-frequency users (Table 5.6), it was expected that any correlation between KRT performance and CAL resource use would be abated by stronger correlations between KRT performance and DA scores. These findings, however, suggest that using of the CAL resource more frequently improved knowledge retention independently of the SAL pathway. Although unexpected, the literature offers several potential explanations for these results. One possibility is that the carefully organized presentation of the content within the CAL resource helped students to form more organized ‘encodings’ of that content in their long-term memory, and the resource’s alignment with the depth and style of the course assessments and KRT questions made the questions more familiar, which aided in the ‘retrieval’ of their knowledge (Biggs and
Tang, 2011; Unsworth, 2016). Furthermore, the interactive design that allowed users to simultaneously reveal pictures, highlighted structures, and corresponding text with each click may have served to better engage students and hold their attention for more active processing of the information than traditional approaches (Mayer and Moreno, 2003; Kumar, 2004). These qualities of thoughtfully designed and curriculum-targeted multimedia tools make them ideal candidates for implementation as supplemental learning resources in human anatomy.

One consistent finding beyond the direct evaluations of the laboratory environment and novel CAL resource in this study is the clear correlation between DAs to learning and knowledge retention. These findings echo the conclusions put forth by various other researchers who concluded that deep information processing improves factual recall (Onion and Slade, 1995), a propensity for DAs to learning is predictive of performance up to six years in the future (McManus et al., 1998), and using deeper approaches to learning aligns with the use of more diverse study strategies and ultimately better knowledge recall after one year (Ward and Walker, 2008). The findings in this study therefore strengthen the case for knowledge retention as an outcome associated with meaningful learning alongside performance quality (Trigwell and Prosser, 1991; Newstead, 1992; Norton and Dickens, 1995; Pandey and Zimitat, 2007) and learning satisfaction (van Rossum and Schenk, 1984; Zimitat and McAlpine, 2003). Furthermore, this evidence reiterates a need for courses to focus on encouraging DAs to learning as a route to high quality learning, regardless of the intervention type (Trigwell and Prosser, 1991).
5.2.5.1 Limitations

The potential for differences between the study population and those who chose not to participate was certainly present. Follow-up analyses found that the population for this study had a lower male to female ratio and higher mean final grades than non-participating students (data not shown); however, there were no significant differences in any other variable between the study population and the course population. Within this study population, however, the mean age of PRO students was significantly higher than that of DI students (Table 5.3). Fortunately, none of these differences were likely to have affected the conclusions of this study since sex and age were treated as contributors to SAL and final grades were included as a performance control in the MLR analyses (Wang et al., 2013; Theobald and Freeman, 2014; Rubin et al., 2016).

The course design may have also had unintended influences on the results of this study and the relevance of the findings for other institutions. Specifically, the ‘enhanced’ PRO method at UG (discussed in Chapter 3) is a deviation from traditional PRO laboratory designs because it includes exposure to dissection progress rather than only completed prosections. It is therefore possible that the shared progression through the content between the DI and PRO cohorts equalized the environments to some degree, minimizing any differences that may have been detected between two more traditional approaches.

There were additional challenges related to the quantification of CAL use and the timing of the KRTs that may have influenced the findings. Namely, the study failed to account for CAL resource use that may have occurred during the extra-laboratory hours offered throughout the course. Since CAL resource use was not recorded during those
times, it is possible that students classified as ‘low-frequency CAL resource users’ had under-represented experience with the CAL resource. A similar argument could be made about the students’ total study time in the course. Since students’ cumulative time spent learning anatomy (from all resources) was not quantified, it is possible that their performance on KRTs was more strongly influenced by their total study time than their frequency of CAL resource use. Furthermore, in addition to exposure in the extra-laboratory hours, all participating students had access to the laboratory through their enrollment in the second-half of the course at the time of the study. Administrative restrictions limited the time-frame for this study to three months after the completion of the fall semester, which corresponded with the midterm examinations for the winter semester. While the winter semester content was different from the fall semester content that was tested in the KRTs, it is possible that the academic climate during the time of the study had unseen influences on the students’ participation rate and knowledge retention.

A further limitation was encountered in the design of the KRTs themselves. The questions in the KRTs were designed to test low-order outcomes that ‘scaffolded’ toward higher-order outcomes related to the same concept (Biggs and Tang, 2011). Theoretically, students would have therefore had to use the knowledge that was assessed in the low-order question to successfully answer the high-order question for each concept. This introduced an element of redundancy that may have disadvantaged some students and advantaged others. However, the overall KRT performance was generally quite low, with few individual scores above 60%. This narrow range of performance may have diminished the strength of the analyses to detect correlations between KRT scores and
the potential explanatory variables. It is also notoriously difficult to test high-order learning processes such as ‘evaluate’ and ‘create’ with short-answer tests (Huxham and Naerra, 1980; Anderson et al., 2001; Thompson and O’Loughlin, 2015). Had questions that targeted these higher cognitive levels been included, more stark differences in performance and a subsequently broader range of KRT scores may have been elicited.

5.2.5.2 Future Directions

Although this study yielded valuable data pertaining to the laboratory environments and a novel CAL resource at UG, similar research at other institutions is required to elucidate the roles of DI, PRO, and CAL in anatomical knowledge retention. Additional research should aim to determine the most relevant and productive contexts and environments for each of these educational approaches to maximize their potential for promoting meaningful and lasting learning. Finally, based on the findings of this and previous studies using the current population (Chapter 3 and Section 4.3), all future educational interventions should be evaluated for their influence on SAL to ensure that they successfully align with DAs to learning and the desired learning outcomes.

5.2.6 Conclusions

Developing lasting anatomical knowledge is imperative for students pursuing careers in the health sciences. Methods of teaching anatomy are under constant evolution to successfully meet this goal despite various extraneous pressures. This study evaluated two popular areas of focus for curricular changes, the laboratory environment and CAL resources, to determine their influences on long-term anatomical knowledge retention. The findings indicated that while participation in the DI or PRO laboratory did not have a
significant influence, students who used a curriculum-targeted CAL resource more frequently had stronger anatomical knowledge recall. DAs to learning were also identified as an important positive predictor of knowledge retention. Therefore, while the laboratory environment undoubtedly plays an important role in student learning, CAL resources may be beneficial as supplemental learning tools to support cadaver-based human anatomy education.
6 Integrated Discussion

6.1 Overview

The work in this thesis aimed to address gaps in the literature related to student learning in different laboratory environments and with modern educational resources. Specifically, the objectives of this thesis were to investigate the influence of the dissection-based (DI) environment, the prosection-based (PRO) environment, and a novel computer-assisted learning (CAL) resource on students’ subjective course experiences (CE), approaches to learning (SAL), academic performance, and long-term anatomical knowledge retention (see Chapter 2 for project-specific objectives and hypotheses). After identifying popular educational interventions in human anatomy and developing a strong theoretical approach to measuring student learning (Chapter 1), these objectives were accomplished by: comparing learning outcomes between students enrolled in DI and PRO laboratory environments (Chapter 3); creating a curriculum targeted CAL resource and assessing its influence on the students’ learning experience and academic outcomes (Chapter 4); and examining the influence of the laboratory environment and use of the CAL resource on students’ long-term ability to recall anatomical knowledge (Chapter 5). The following sections will discuss the major findings of the research outlined in this thesis, present the strengths and limitations of the overall work, and suggest avenues for future research in this domain.

6.2 Summary and Discussion of Major Findings

The landscape of human anatomy teaching is constantly evolving to accommodate for extrinsic pressures related to limitations in time and resources. This has prompted
several educational interventions and modifications to traditional anatomy learning environments that alleviate various issues related to cost and student time commitments. Two of the most popular departures from the traditional DI laboratory are the PRO laboratory and CAL resources. These interventions have different magnitudes of impact – the PRO laboratory is a fundamentally different learning environment from DI (see Section 1.2.2), while CAL resources are usually used to supplement an existing learning environment (see Section 1.2.3). With any change in the academic environment, however, it is important to establish its impact on student learning to ensure the highest possible quality.

Academic success is a broad and amorphous measure; however, most agree that it encompasses more than simply performance (see Section 1.3). There is a general consensus that the majority of outcomes associated with academic success, especially the more qualitative ones, relate to how deeply students engage with the learning environment and its associated activities, which is reflected in scores of SAL (see Section 1.3.2). Ergo, different learning environments (i.e., DI and PRO laboratories) and new learning resources (such as CAL tools) can directly influence SAL and, ultimately, the outcomes of the students’ learning. Considering the different magnitudes of change represented by these two interventions, it was important to first establish the influence of the overall laboratory environments on student learning before investigating the less drastic perturbation of introducing a novel CAL resource.
6.2.1 Study One

To investigate the influence of the laboratory environment, Study One compared learning outcomes between students enrolled in the DI and PRO laboratory cohorts at the University of Guelph (UG) (Chapter 3). This study addressed an existing gap in understanding of how DI and PRO laboratory environments influence SAL and the subsequent quality of students' learning. The primary finding of the study was that although there were no significant differences in mean SAL scores between DI and PRO students, participation in DI was associated with higher deep approach (DA) to learning scores when potentially confounding factors were controlled for. These results suggest that the more active task of dissection may have encouraged students to engage more deeply with the content, resulting in a more meaningful learning experience. This outcome is consistent with the hypothesis presented in Section 2.2.1. Accordingly, it was expected that DI students would perform better on all course assessments; however, this hypothesis was only partially accurate. The only category in which DI students outperformed PRO students was on the group laboratory oral assessments (Chapter 3). These assessments were isolated from the final grade to represent various skills related to oral presentation (i.e., communication, teamwork, etc.) as well as basic anatomical competency. Although this correlation may suggest that the DI environment had a role in the promotion of skill development, the data do not provide a conclusive or direct link between these two phenomena. Furthermore, DI students did rate their CE higher for generic skill development than PRO students; however, the difference was not significant.
Ultimately, more research into skill development as an outcome of learning in human anatomy is warranted.

Although the findings from Study One suggest an advantage to DI over PRO, they do not significantly diminish the value of PRO. Students in both laboratory environments reported high mean DA to learning scores, which did not significantly differ in magnitude (Chapter 3). Although those specific analyses did not control for demographic and situational factors (i.e., cumulative grade average, sex, subjective CE, etc.), the results suggest that participation in PRO may have promoted some degree of beneficial deep learning. Furthermore, performance on written and laboratory examinations did not differ between DI and PRO students, even when potentially confounding variables were controlled for (Chapter 3). Coupled with the findings related to SAL and statistically equivalent subjective CE scores between the cohorts, these results indicate that PRO may offer a valuable teaching approach at institutions facing limitations to their available time and resources.

6.2.2 Study Two

After a baseline understanding of student learning in DI and PRO environments was established in Study One (Chapter 3), more specific elements of the learning process could be investigated. Namely, work had begun on a CAL tool that was intended to act as a self-directed laboratory learning resource for students in both laboratory cohorts (see Section 4.2 for a detailed description of the theoretical and technical design considerations for the resource). This resource was incorporated into the DI and PRO laboratories in the fall semester of 2016 and students were given free access to it during
all laboratory hours. In Study Two, the students’ use of the resource was monitored and used to determine the impact it had on learning in the course (Section 4.3).

The first objective of Study Two was to establish a general understanding of how the novel CAL resource affected learning in the course in Fall 2016 compared to Fall 2015. Accordingly, the students’ ratings of their CE, SAL, and their academic performance were compared between those enrolled during the Fall 2015 semester (no CAL resource access) and the Fall 2016 semester (open CAL resource access). Surprisingly, although Fall 2016 students rated the course significantly higher both overall and on several CE scales, including learning resources, they reported lower DA scores and higher surface approach (SA) scores than Fall 2015 students. At first, these results appeared to suggest that the CAL resource may have contributed to a more surface-oriented learning environment; however, these results should be interpreted with caution as they represent direct comparisons that did not control for potentially mitigating factors, nor did they acknowledge the Fall 2016 students’ experience using the CAL resource. Overall, perceptions of the course (including the Learning Resources scale of the Course Experience Questionnaire) were higher in 2016 than 2015, indicating that the CAL resource was well received by students. Furthermore, Fall 2015 and Fall 2016 DI students did not perform significantly differently in the course and Fall 2016 PRO students out-performed their Fall 2015 counterparts. Ultimately, because the conflicting results of the comparisons between cohorts do not control for direct characteristics of CAL resource use, they are best used only as descriptive measures of CE, SAL, and academic performance.
To address these concerns, the Fall 2016 students were examined in isolation to determine if their frequency of CAL resource use was related to SAL or course performance. While no direct correlations between CAL resource use and SAL score or course performance were found, the students’ perceptions of the resource were positively correlated with DA to learning scores. This finding addresses an important gap in the literature. Specifically, several studies have found that students report overwhelmingly positive perceptions of CAL resources, but they did not determine (or sometimes even investigate) a link to measurable learning outcomes; conversely, CAL has been regularly studied alongside measures of academic performance with mixed results (Losco et al., 2017). While the beginning and end of the learning cycle have therefore been addressed, very few studies have considered what happens in the middle – how CAL resources influence the process of learning. Thus, the link between CAL resource satisfaction and DAs to learning demonstrated in Study Two may offer one explanation for how CAL resources can improve the quality of learning through enrichment of the learning process. This is an important finding, given the known associations between DAs to learning and meaningful learning outcomes (see Section 1.3.2).

Arguably the most valuable information gathered in Study Two, however, was the written feedback from students outlining their perceptions of the CAL resource (Section 4.3). Not only did these comments provide constructive information for future developments to the resource, but they also highlighted important considerations for educators at other institutions who are considering CAL for their courses. Namely, the feedback indicated that students appreciated having a clear and detailed tool for
reference and review that allowed them to see the material presented in a different way. Furthermore, their comments strongly identified a desire for more free and open access to the resource online. This would have allowed them to spend more time with the resource and perhaps engage more deeply with the content. Additional insights detailing how the design of the resource could be improved, such as increasing the ease of navigation, ensuring alignment with the course, and adding a self-testing component, may benefit other anatomy educators in the creation of their own CAL resource. Overall, these and other insights obtained through Study Two contribute important information that can be used to better understand the role of CAL in human anatomy education and optimize its characteristics and disseminated context to improve learning quality.

6.2.3 Study Three

A principal goal of undergraduate human anatomy programs is to give students the tools that prepare them for more advanced study or a career in the health sciences. After establishing the influences of the laboratory environment and use of a CAL resource on more proximal learning outcomes (subjective CE, SAL, and academic performance) in Studies One (Chapter 3) and Two (Section 4.3), Study Three (Chapter 5) therefore aimed to elucidate the role of these factors on long-term knowledge retention.

To test this outcome, Study Three was conducted in two parts. In the first part, participants were grouped based on their laboratory enrollment. Scores on anatomical knowledge recall tests were then directly compared between DI and PRO students and predicted from a series of potential explanatory variables, including laboratory enrollment. Because DAs to learning have been associated with stronger knowledge recall ability
(Ward and Walker, 2008) and a correlation was observed between participation in DI and DA to learning scores in Study One (Chapter 3), it was expected that DI students would have higher knowledge recall scores. However, while DAs to learning were correlated with knowledge recall scores in Study Three, laboratory enrollment was not a significant contributor (Chapter 5). These results indicate that the laboratory environment is not the primary driver of lasting knowledge, but the depth with which the students interact with that environment may play a significant role. However, taken alongside the correlation between participation in DI and DAs to learning (Chapter 3), the DI laboratory appears to best facilitate this goal. This is a very relevant finding in the field of anatomy education, as this is, to the best of the author’s knowledge, the first body of work to establish this link. Accordingly, this work adds more fuel to the fiery debate surrounding different laboratory environments for teaching human anatomy.

The second part of Study Three examined the role of CAL in long-term anatomical knowledge retention. These analyses found that high-frequency CAL users outperformed low-frequency CAL users on all measures of knowledge retention (Chapter 5). However, when SAL and other potentially contributing factors were accounted for in multiple linear regression analyses, the only persistent trend was that the students’ frequency of CAL use was positively correlated with their performance on high-order knowledge recall questions. This suggests that use of the CAL resource was a primary driver behind the students’ ability to better retain anatomical knowledge and use it to perform complex cognitive tasks. Again, however, the most consistent indicator of knowledge retention was DA to learning score. In fact, all analyses indicated that students
with higher DAs to learning had better knowledge recall scores (Chapter 5). This provides further evidence that every effort should be made to include resource interventions that encourage DAs to learning. Recall, Study Two found that students who reported higher satisfaction ratings of the CAL resource also had higher DA to learning scores (Section 4.3). Since it stands to reason that students who perceived the tool to be more valuable to their learning would use it more frequently, it is possible that this CAL resource contributed to stronger long-term knowledge retention both directly through its use and through the promotion of DAs to learning. Moreover, if the students' feedback from Study Two is considered during the development of future editions of this resource, their satisfaction with the resource and potentially their DAs to learning may see further improvement. Accordingly, applying the lessons learned from Study Two to the procedures outlined in Section 4.2 may help anatomy educators at other institutions to develop their own powerful CAL tools that improve the quality and impact of their program. Furthermore, the resource created for this thesis may be used to extend the reach of the human anatomy program of UG through the development of an online anatomy course for non-health sciences majors.

6.3 Limitations

Several, mostly unavoidable, circumstances limit the reach of this work. The most significant of these is likely the contextual nature of educational research in general. The studies conducted for this thesis used participants from third-year non-medical undergraduate programs at UG. Since the majority of human anatomy education research occurs at the medical level, the findings of this study may not be fully generalizable to the
larger audience of anatomy education researchers. However, its specificity is also a strength of this work. Although many undergraduate and otherwise non-medical institutions provide human anatomy courses, very few studies focus on these learners. Accordingly, this thesis may contribute to the field by acknowledging outcomes that are meaningful to all levels of learner in the health sciences, not just medical students.

Another potential confound of this work is the nature of the specific DI and PRO laboratory environments at UG. This specificity presents essentially another context-related problem. While the DI laboratory design is similar to DI environments students would encounter at most other institutions, the ‘enhanced’ PRO design involves a different style of learning than the traditional PRO design. Explicitly, the week-to-week stepwise reveal of relevant structures on the shared donors between DI and PRO students gives PRO participants a more immersive experience that may have contributed in part to the depth of their learning approaches. It is therefore possible that more pronounced differences in learning outcome success between DI and PRO students would be observed in contexts that used more traditional approaches.

A third, but equally important, limitation relates to the accuracy of recording students’ activity in the laboratory. Specifically, student attendance was not accurately or consistently recorded during the several extra open-laboratory hours throughout both the Fall 2015 and Fall 2016 semesters. Because of this, it is possible that some students’ extra time in the laboratory may have influenced the various learning outcomes assessed in this thesis in ways that could not be controlled for because it was un-recorded. This opens the possibility that the observed influences of the DI and PRO laboratory
environments on learning are artifacts of extra laboratory study time. Furthermore, students had access to the CAL resource during these times, so a large amount of their CAL resource use may have gone un-reported. It is difficult to speculate how this may have influenced the results, but it does reflect an important procedural omission. However, in all of the analyses in this thesis, every effort was made to include factors that may have accounted for the lapse in data surrounding the extra laboratory hours. For instance, anecdotal knowledge derived from years of experience with the course in question (both on the part of the author and the advisor, Dr. Lorraine Jadeski) indicates that the particularly keen students are the most frequent extra laboratory session attendees. Accordingly, the students' cumulative grade averages were controlled for in all of the relevant regression analyses as a proxy measure for student aptitude (Theobald and Freeman, 2014). This inclusion should have offset some of the potential bias incurred by the un-recorded extra laboratory session attendance.

6.4 Suggestions for Future Research

Although the studies included in this work answered many of the questions that initially prompted this research, they also unearthed new potential areas of inquiry. First, as far as local research is concerned, future studies should be conducted to establish the role that participation in the extra laboratory sessions plays in influencing students’ CE, SAL, performance and knowledge retention. Furthermore, future observational studies may be beneficial for understanding what the students are specifically doing in the laboratory (i.e., what resources they use and how often) and how different study behaviours influence these learning outcomes. These types of studies may uncover
findings that could help inform improvements to the design of the course and provide students with useful insights into the most successful study approaches in the course.

More broadly, this work elicited several questions surrounding student learning and the optimal delivery of laboratory-based human anatomy education. For one, the findings outlined in Chapter 3 suggested that there may be a connection between participation in DI and students’ skill development; however, the evidence was insufficient to make a definitive conclusion. This highlights a need for further investigations that use skill development as a primary learning outcome measure; however, more research is required to determine how best to do so. Another potential extension of this work is to continue observations of DI and PRO students to evaluate their success in their advanced degrees and their ultimate careers to determine if participation in DI or PRO is predictive of future success in certain fields. Considering the observation that students who aspired towards careers in physical therapy were significantly more likely to choose PRO in Fall 2015 (Chapter 3), this proposed avenue of future research may help determine if that choice could be recommended to future students.

Finally, a wealth of future research surrounding the CAL resource came to light as a result of the research in this thesis. Namely, in addition to various constructive comments for improvements to its design, the student feedback obtained in Study Two echoed a predictable sentiment – to disseminate the CAL resource online for improved accessibility. Accordingly, future research should heed this call and study whether improved access to the resource has a measurable effect on students’ learning outcome achievement. Such a move would also open the possibility for studies using different
populations of students such as those in non-health sciences majors or at other institutions. Studies such as these will also foreseeably inform even more developments and improvements to the resource.

6.5 Conclusion

The goals of this research were to evaluate student learning in DI and PRO human anatomy laboratory environments, as well as to determine the impact of a curriculum targeted CAL resource on student learning in these environments. The major findings of this work indicated that while PRO can be a valuable teaching design, DI may encourage deeper learning approaches and promote stronger skill development. Furthermore, CAL resources that elicit strong satisfaction among students who use them may promote DAs to learning and benefit long-term knowledge retention. Taken together, the results of the studies contained in this thesis support the use of DI and supplemental CAL resources for human anatomy education and advocate for research into multiple and nuanced learning outcomes when assessing novel educational interventions.
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APPENDICES

See attached media files for Appendices A – H.