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Exploring Current Topics and Trends in Anatomy Education: A Scoping Review

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Abstract

Within the field of health professional education, one finds that anatomy often presents students with a great deal of difficulty. The literature in this area is piecemeal and there is limited work available examining the whole of this topic. A scoping review was conducted to determine how students are taught anatomy across multiple disciplines (medicine, dentistry, rehabilitation sciences, and undergraduate education) and to assess for any notable differences between these populations. The results found that scholarship on anatomy instruction varies based on educational context, and medical students are the most frequently targeted student population. It also found that the use of medical imaging and computer aided instruction is increasing while the use of cadaveric dissection has remained constant. Furthermore, the lack of cadaveric dissection in an anatomy curriculum does not necessarily hinder student learning when alternative teaching modalities are implemented.

Lay Summary

Anatomy is a complicated subject for students to learn, but it is critical in the delivery of safe clinical care by healthcare practitioners. Due to the complexity of anatomy, many healthcare professionals do not receive sufficient anatomy training. This thesis used a scoping review to capture how anatomy is taught to different student populations to assess the methods with which students are taught anatomy. It is expected that understanding this aspect of student education in the subject of anatomy will help lead to better educational outcomes.

Keywords

Anatomy, education, teaching, learning, undergraduate, graduate, medical, dentistry, nursing, physiotherapy, physical therapy, occupational therapy, cadaveric dissection, prosection, medical imaging, computer-aided instruction, plastination, living anatomy, lecture-based learning
# Table of Contents

Abstract i

Lay Summary i

Keywords i

Table of Contents ii

List of Tables iv

List of Figures v

List of Abbreviations vi

Acknowledgements vii

Introduction 1

Background 2

Why Anatomy Education is Important 6

The Changing Environment: Shifts in Anatomy Education 8

Considering the Current State of Anatomy Education 10

Objectives 12

Methods 13

Identifying the Research Question 13

Identifying the Relevant Studies 14

Study Selection 15

Charting the Data 16

Collating, Summarizing, and Reporting Results 16

Results 18

Demographic Features 18

Distribution of Studies by Body Regions and Systems 18

Distribution of Studies by Student Population 19
**List of Tables**

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Student Population, Classification, Tool Used, and Targeted Body Region</td>
<td>24</td>
</tr>
<tr>
<td>2</td>
<td>Cross Referencing Educational Tools by Student Population</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>Classification and Grouping of Anatomy Learning Tools</td>
<td>65</td>
</tr>
</tbody>
</table>
List of Figures

Figure 1: Outlining the Article Selection Process. 17
Figure 2: Distribution of Rejection Criteria 34
Figure 3: Proportion of Student Population 35
Figure 4: Total Number of Sources by Year 36
Figure 5: Trends Across Educational Interventions by Year 37
Figure 6: Total Number of Sources by Country 38
Figure 7: Body Regions Targeted in Literature 39
Figure 8: Body Systems Targeted in Literature 40
Figure 9: Percentage of Category 42
Figure 10: Percentage of Categories (Novel Classification) 67
List of Abbreviations

AR: Augmented Reality
CAI: Computer Aided Instruction
CBL: Case-Based Learning
CT: Computed Tomography
IBL: Inquiry-Based Learning
MRI: Magnetic Resonance Imaging
PBL: Problem-Based Learning
SDL: Self-Directed Learning
TBL: Team-Based Learning
VR: Virtual Reality
3Dp: Three Dimensional Printed (model)
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alex wolf
Introduction

Since its origins, anatomy has had a rich and fascinating history. It has been a cornerstone of medical education for hundreds of years and has stood the pedagogical test of time (Turney, 2007). For many centuries, cadaveric dissection was the basis of both anatomy education and medical education in general (Azer & Eizenberg, 2007; Vázquez et al., 2007).

Anatomy education is a discipline that has been shaped by its history (Finn & McLachlan, 2010). Many great minds have pondered the inner workings of the human body. Da Vinci produced many anatomical drawings, still prized today for their accuracy and intricate drawing technique (Bell & Evans, 2014). Galen's anatomical descriptions ruled the medical world for over 1500 years after his death. Herophilus was the first anatomist to be authorized to dissect a human body, and did so around 600 times (Calkins, Franciosi, & Kolesari, 1999). Vesalius, the father of modern anatomy, provided anatomic illustrations of surpassing quality rooted in meticulous dissection (Calkins et al., 1999). What these minds share in common is that their exploration of human anatomy was grounded in human dissection. The use of dissection was essential for accurately depicting the internal structure of the human body (Calkins et al., 1999).

Anatomy education has had the longest history of any component of medical education, and cadaveric dissection has been the predominant paradigm of anatomy education since the Renaissance (McLachlan & Patten, 2006). Many academics strongly support the use of cadaveric dissection as an integral part of anatomy education (e.g., Ahmad, Sleiman, Thomas, Kashani, & Ditmyer, 2016; Ramsey-Stewart, Burgess, & Hill, 2010).

As time has progressed, so too has anatomy and how it is taught. Cadavers are used less and less in educational settings; the halcyon days of hundreds of hours spent on anatomy instruction, dissection, and exploration have given way to the urgent and fast-paced environment of educating today's health care professionals.
Background

This paper will provide a background into different approaches to teaching anatomy at different levels of post-secondary education to different student populations. Then, the paper will address whether or not there are clear differences in teaching curriculum or student expectations between different student populations taking anatomy courses.

Educational Context

For this review, several student populations were considered, including:

1. Medical students
2. Dentistry students
3. Nursing students
4. Rehabilitation sciences students, including:
   1. Physiotherapist students,
   2. Occupational and physical therapy students
5. Undergraduate students

Physiotherapy, occupational therapy, and physical therapy students are considered one student population due to their similar training and career paths. Undergraduate students are unique from the rest of the student population because their degree type is not expected to lead them to a patient-focused career immediately after receiving their diploma. However, because these students may still take anatomy courses throughout their undergraduate degrees, they are an important population to take into consideration.

In general, these student populations vary in one key regard: whether the degree they are pursuing will lead them to patient-centred careers immediately after graduation. In North America, medicine, dentistry, and rehabilitation sciences programs require an undergraduate degree before students may pursue these studies. Compressed timeframe nursing programs may require an undergraduate degree before students can enrol. There are, however, exceptions to this. In Europe, students wishing to pursue these degrees may do so directly from their high school
studies, or after completing an undergraduate degree. Nursing will also lead to patient-centred careers immediately after graduation but do not require undergraduate degrees before the commencement of studies. What remains constant in each of these professions is that practitioners require a sound understanding of anatomy in order to successfully and safely care for their patients.

Conversely, anatomy can be taught at the undergraduate level in numerous different degree programs (such as biology, health sciences, kinesiology, medical sciences, pathology, and so on), but the anatomy encountered in these degrees does not immediately translate into the clinical or healthcare setting. In the case of undergraduate students, anatomy may be a required course for the program or an elective a student opts to undertake. This makes the undergraduate population unique, because the anatomy students learn might not directly relate to the career they pursue. However, the anatomy which students encounter during their undergraduate degrees may serve them later while pursuing other degrees and programs in health professions.

**Teaching Modalities**

Estai & Bunt (2016) have recognized and explored the common tools used to teach anatomy to students. This paper was selected as a framework for this scoping review for its inclusion of a variety of teaching methods. The use of an existing scholarly paper as a foundation adds more rigour to the findings of this scoping review. In their paper, they identify nine major categories of teaching tools to aid medical students in learning anatomy:

1) **Cadaveric dissection:** the primary tool used to teach anatomy over the last 400 years, considered by some to be indispensable to learning anatomy (Netterstrøm & Kayser, 2008, as cited in Estai & Bunt, 2016). Not only does it aid in understanding and learning anatomy, it also contributes to medical professionalism and first encounters with death. However, this method is costly and time-consuming (Aziz et al., 2002, as cited in Estai & Bunt, 2016). Therefore, it has been suggested that dissection is only necessary for students that will

2) Prosections: dissections prepared for students by professional anatomists, reducing the number of cadavers needed to teach the same number of students. Prosections are better matched to system-based courses, rather than dissections that are conducive to anatomy taught by region (Leung et al., 2006, as cited in Estai & Bunt, 2016). Furthermore, they address some of the drawbacks of dissection, such as costs and time, and require fewer cadavers per student (Dinsmore, Paul, & Sweet, 1993; Nnodim, 1990; Pather, 2015, as cited in Estai & Bunt, 2016). However, they are dependent on the skill of the professional generating the prosections.

3) Plastination: a method of preserving prosections, offering cost-effectiveness through increased longevity. Despite these advantages, they do experience shrinkage, loss of finer details, and loss of texture. Like prosected and dissected material, they need to be renewed; but still offer cost effectiveness through longer usage times and cheaper storage methods (Latorre et al., 2007, as cited in Estai & Bunt, 2016).

4) Computer-aided instruction: enabled by recent advances in technology, computer aided instruction (CAI) resources have been implemented in response to reductions in teaching time and budgets, increased class sizes, and increased costs of cadaver labs. Studies examining their efficacy suggest that there is no clear proof that CAI alone is a superior approach than more traditional methods (Khot, Quinlan, Norman, & Wainman, 2013; McNulty, Halama, & Espiritu, 2004, as cited in Estai & Bunt, 2016), and are best used as a supplement to enhance learning rather than replacing traditional teaching methods (Durosaro, Lachman, & Pawlina, 2008, as cited in Estai & Bunt, 2016; Tam et al., 2010). A big domain within this category is the use of 3D representations of anatomy and virtual reality.

5) Medical imaging: considered a valuable addition to dissection courses. Medical imaging provides in vivo visualization of anatomy (Gunderman & Wilson, 2005, as cited in Estai & Bunt, 2016). Incorporating medical imaging into anatomy education may promote better understanding of spatial relationships (Pabst,
Westermann, & Lippert, 1986; Reeves, Aschenbrenner, Wordinger, Roque, & Sheedlo, 2004, as cited in Estai & Bunt, 2016). However, like CAI resources, it functions poorly as a standalone teaching modality (Aziz et al., 2002; Howe, Campion, Searle, & Smith, 2004, as cited in Estai & Bunt, 2016) and might be better used as an adjunct to other teaching methods. Furthermore, medical imaging cannot replace conventional dissection (Aziz et al., 2002; Gunderman & Wilson, 2005; Howe et al., 2004, as cited in Estai & Bunt, 2016).

6) **Living anatomy**: offers students the ability to safely practice clinical skills and is also considered more cost effective. Living anatomy often takes the form of peer physical examinations, ultrasonography, and body painting. This method is considered more cost effective than the use of real patients or model patients (Wearn & Bhoopatkar, 2006, as cited in Estai & Bunt, 2016). Body painting involves drawing anatomical structures on the body’s surface, which is an active and tactile learning modality (Op Den Akker, Bohnen, Oudegeest, & Hillen, 2002, as cited in Estai & Bunt, 2016). Ultrasonography, however, is not widely taught in medical school (Brown, Adhikari, Marx, Lander, & Todd, 2012a).

7) **Lecture-based teaching**: while lectures have remained a key part of anatomy education alongside dissection over the previous four centuries (Vázquez et al., 2007), it is criticized as outdated and ineffective. An alternative to this method is blended learning, which involves the integration of face-to-face teaching and online instruction (Graham, 2006, as cited in Estai & Bunt, 2016).

8) **Integrated curricula**: specific areas of anatomical knowledge can be prioritized according to the needs of the student; minimal anatomy is taught to students working towards general practice and students working towards surgery or other specialized areas can receive advanced training later in their education. With this approach, core anatomical knowledge can be gained at the most appropriate level (Evans & Watt, 2005, as cited in Estai & Bunt, 2016).

9) **System-based curricula**: learners can master one system of the body throughout all the body’s regions before moving on to the next system, which has been found to be easier than learning the body by regions (Brooks, Woodley, Jackson, & Hoesley, 2015), and improve long term retention of the material (Arslan, 2014, as cited in Estai & Bunt, 2016).
The categories described by Estai and Bunt (2016) will serve as a guiding framework for this scoping review. While the nature of the Estai and Bunt paper is similar to this paper, there are some critical differences that distinguish the documents. First, the article focuses exclusively on students undertaking medical degrees, while the student populations included in this paper expands beyond undergraduate medical education. Second, the work of Estai and Bunt (2016) focuses solely on teaching modalities and strategies for medical students, rather than teaching strategies employed for a wider range of student populations. Finally, the work of Estai and Bunt (2016) can be considered a traditional literature review. The current paper undertakes a rigorous and formalized scoping review approach which will compliment and expand upon the work of Estai and Bunt (2016). The purpose of this paper is to capture the different approaches to teaching anatomy across multiple student populations and to identify many of the tools educators use to teach their students as possible.

**Why Anatomy Education is Important**

For the medical student, anatomy is considered one of the cornerstones of medical curricula (Brooks et al., 2015; Topping, 2014), and the foundation of clinical skills (Ahmed et al., 2010; Cuddy, Swanson, Drake, & Pawlina, 2013; Estai & Bunt, 2016; Kerby, Shukur, & Shalhoub, 2011). Anatomy learning is seen as an essential component of medical training (Ma et al., 2016) and to medical practice itself (McLachlan, Bligh, Bradley, & Searle, 2004). Competent physicians and surgeons require a deep and complete understanding of anatomy for safe clinical practice (Estai & Bunt, 2016). Anatomy is the basis of modern medicine (Chen et al., 2017).

While anatomy is particularly relevant to the field of surgery, it remains relevant to all health care specialties (Ma et al., 2016; Sugand, Abrahams, & Khurana, 2010). Nurses, physiotherapists, physical therapists, occupational therapists, audiologists, speech language pathologists, and dentists all require a deep understanding of anatomy for their practice, even if their knowledge of anatomy is limited to a certain region or system of the body. While these professionals might specialize in a
particular region or system of anatomy, it is still important for that professional to be well versed in that anatomy for safe and successful practice. As is the case for medical students, anatomy serves as a basis for their clinical skills. Visualizing the structure of the human body is critical for building a strong clinical knowledge base (Carter, Patel, Hocum, & Benninger, 2017).

The outcome of professional patient care has been found to be based on the level of anatomy knowledge of the health care professional (Smith & Mathias, 2010). Too often, students learn anatomy to pass examinations while forgetting details afterwards (Smith & Mathias, 2010), which does not establish a positive and sound understanding of anatomy for safe clinical practice. All health care professionals will be required to apply their anatomical knowledge in diagnostic or therapeutic contexts throughout their career (Sweeney, Hayes, & Chiavaroli, 2014). The changes in medical curriculum, in particular, reflect this, as the preoccupation with technical knowledge has transitioned into attitudes and skills for patient care (Dinsmore et al., 1993). Moreover, anatomy is an essential communication tool for healthcare professionals, as it is a common platform of knowledge suitable to all healthcare careers (Turney, 2007). Therefore, anatomy also takes on a professional aspect.

The link between anatomy and clinical skills is an important one. Anatomy knowledge serves as a foundation upon which clinical knowledge and skills can be built (Cuddy et al., 2013). Learning and developing clinical skills depends on understanding relevant and interrelated surface anatomy, clinical anatomy, and radiological anatomy (Dangerfield, Bradley, & Gibbs, 2000). Anatomy knowledge permits the safe execution of skills in the clinical setting and results in better outcomes for patients.

However, the reduction of anatomy in curricula compromises the opportunity for students to learn and safely practice clinical skills, and compromises patient outcomes. In the last three decades, there has been a downward trend in the amount of hours devoted to anatomy education (Craig, Tait, Boers, & McAndrew, 2010; Drake, McBride, Lachman, & Pawlina, 2009; Shaffer, 2004; Sritharan, 2005).
Over approximately five decades, time given to anatomy and dissection in US medical schools has declined by 50% with an 11% reduction on average between 2002 and 2009 (Drake et al., 2009). There is also a great deal of variability in the number of hours dedicated to anatomy in anatomy courses in higher level education within the same country. For example, this is seen in Ireland (Heylings, 2002), as well as Australia and New Zealand (Craig et al., 2010). The variability between institutions in these countries, as well as the global differences in level of anatomy instruction, implies that the time dedicated to anatomy education is insufficient or incompatible with safe clinical practice. If one institution believes the level of anatomy being taught to students is sufficient yet it differs from a second institution, it must be concluded that at least one institution (if not both) must therefore be incorrect about their assumptions as to what constitutes an appropriate level of anatomy instruction.

The Changing Environment: Shifts in Anatomy Education

As demonstrated (e.g., Cuddy et al., 2013; Smith & Mathias, 2010; Sweeney et al., 2014), the link between anatomy and safe clinical practice among health care practitioners is highly supported throughout the literature. A reduction in the quality and quantity of anatomy teaching results in deleterious outcomes for professional practice across many domains of healthcare.

This reduction of teaching hours and resources dedicated to anatomy instruction has caused worry among healthcare professionals, educators, and students alike. Some professionals have suggested that the level of anatomy education has fallen below a safe level (Fitzgerald, White, Tang, Maxwell-Armstrong, & James, 2008; Turney, 2007). Many practitioners feel that medical students’ knowledge of anatomy is inadequate (Dusseau, Knutson, & Way, 2008). Curricular time for gross anatomy is often an area of concern for anatomy instructors (Brooks et al., 2015); instructors find themselves teaching an "overview" of the human body rather than allowing students to explore and investigate the human body (Gillingwater, 2008). Students themselves have also reported that they feel their level of anatomy education is insufficient (Fitzgerald et al., 2008; Mitchell & Batty, 2009; Watmough, O’Sullivan, &
Taylor, 2010) and requires more structure and time dedicated for safe clinical practice (Ahmed et al., 2010).

It is not surprising that changes in anatomy curricula have degraded intended learning outcomes expected from anatomy education (Ahmed et al., 2010). The misunderstanding that anatomy is content-driven, rather than skills based, may be to blame for the reduction of teaching hours dedicated to anatomy (Patel & Moxham, 2006), especially in medical contexts. Other reasons for curricular change include increasing subject matter integration and the increased use of electronic and technological resources (Drake et al., 2009). Finally, anatomy is no longer seen as a research-led discipline (McLachlan & Patten, 2006; Yammine, 2014), furthering the decline of hours and interest dedicated to anatomy.

Anatomy education has undergone many changes in its curriculum, teaching modalities and resources, and assessment methods (Hadie et al., 2017). The advancement of technologies and electronic devices necessitates changes in academic methodologies (Ferrer-Torregrosa, Torralba, Jimenez, Garcia, & Barcia, 2015). To improve anatomy education, changes and innovations in teaching and assessment are required (Bergman et al., 2013). However, when designing curricula, instructors are often prone to focusing on teaching methods over learning outcomes, even though learning outcomes should take priority (Patel & Moxham, 2008).

A tangible outcome of the recent changes is increased litigation for medical malpractice. “Anatomical ignorance” has led to more malpractice suits brought against doctors (Waterston & Stewart, 2005). However, it remains difficult to determine what level of anatomy education is safe for clinical practice (Craig et al., 2010; Waterston & Stewart, 2005). This is an important aspect to consider. Universities cannot afford to produce negligent medical graduates whose careers often last about 40 years (Sugand et al., 2010). Likewise, other healthcare workers who have long careers working with patients need to be able to safely practice their
profession, and one of the pillars of safe practice is a sound understanding of anatomy.

Traditional methods of learning anatomy purely from cadavers, textbooks, and lectures are becoming obsolete and historical (Finn, White, & Abdelbagi, 2011). Medical schools have been moving away from cadaveric dissection, instead employing the use of prosections, living anatomy, and plastic models (Griksaitis, Sawdon, & Finn, 2012). The traditional teaching methods are criticized for being teacher centred and for treating students as passive participants (Kolossvary, Szekely, Gerber, Merkely, & Maurovich-Horvat, 2017). Anatomy education often makes the mistake of assuming students form a homologous group (Lufler, Zumwalt, Romney, & Hoagland, 2010). This assumption leaves students at a disadvantage, as learners inevitably fall through the cracks of an education system that is failing them.

Despite the criticism aimed at anatomy education, there is a great deal of positivity centred around new teaching methods. The quality of current curricula can be improved through implementing novel teaching methods and tools (Ahmed et al., 2010). The exponential increase in technology and its adoption in society provides exciting new learning tools, and new understandings of more traditional teaching methods.

Considering the Current State of Anatomy Education

Anatomy instruction is at a crossroads (Shaffer, 2004). Traditional anatomists have questioned and challenged the advent of new teaching methods (Tam, Hart, Williams, Heylings, & Leinster, 2009), while proponents of these teaching methods often fail to see the value of traditional teaching modalities (Heylings, 2002). Despite rhetoric from both sides of this schism, there seems to be no clear answer to the question, “what is the best way to teach anatomy to students?” Some scholars answer that there is no single method that can function as an answer to this question (Bergman, 2015). No single teaching method has been proven to be superior to the rest (Johnson, Charchanti, & Troupis, 2012; Turney, 2007), and
perhaps no individual method ever will. The closest any single teaching modality has come to being superior to all others is cadaveric dissection, which is still regarded as the “gold standard” of anatomy education by scholars and doctors alike (Parker, 2002; Patel & Moxham, 2008).

It can be difficult for instructors to determine the best tools and strategies to employ due to the plethora of available choices (Vázquez et al., 2007). Some studies argue for the use of multiple teaching modalities in combination to encourage student learning (e.g., Estai & Bunt, 2016; Finn & McLachlan, 2010; Ivanusic, Cowie, & Barrington, 2010; e.g., Mitchell & Batty, 2009; Peeler, Bergen, & Bulow, 2018; Snelling, Sahai, & Ellis, 2003). Others argue that both traditional and technology-based approaches should be used together when teaching students (e.g., Codd & Choudhury, 2011; Elizondo-Omaña, Guzmán-Lópe, & García-Rodríguez, 2005; Jarral, Mehboob, & Ashraf, 2017; Kugelmann et al., 2018; Stewart & Choudhury, 2015; Yeom, Choi-Lundberg, Fluck, & Sale, 2013). In both arguments, there is a commonality in the belief that multiple different teaching methods used together may facilitate learning. However, the question then becomes; “which teaching methods are best used in combination, and which teaching methods don’t work well with others?” There is no clear answer to this question either. And amidst all this debate among scholars, students still report a tendency to prefer traditional teaching methods over other learning resources (Choi-Lundberg, Cuellar, & Williams, 2016). To this point, McLachlan and Patten (2006) still argue that dissection should remain a key aspect of anatomy education to prepare health professional students for future clinic work.

The best way to teach anatomy continues to be debated among scholars (Elizondo-Omaña et al., 2005; Estai & Bunt, 2016; Tam et al., 2009), and will likely continue to be debated for the foreseeable future. As the debate continues, medical professionals are sent into the healthcare system lacking a proper level of anatomy training, and this puts patients at risk for harm, and professionals at risk for litigation. This may not be a concern for undergraduate students who are not directly entering into the healthcare system, but they are still an important student
population to consider because the anatomy they learn in their undergraduate degrees may become the foundation for the anatomy they learn while preparing for their patient-centred careers. After all, the things one learns first are the most influential (Miller, 2000).

**Objectives**

The purpose of this study is to examine the various teaching methods used across differing student populations. In particular, the study asks the following questions:

1) How does the existing literature on anatomy education describe the various approaches to teaching anatomy to different student populations engaged in clinical or non-clinical degree programs?

2) Are there clear differences in how different student populations are taught anatomy?

A scoping review is employed to gather literature and research studies pertaining to the research question; whether or not there are differences in anatomy education across student populations. This study includes a breadth of student populations to provide a wholistic understanding of trends and themes related to teaching anatomy. It is expected that the unique student populations would capture a wide variety of teaching methods.
Methods

The approach taken for this scoping review followed the recommended stages set out by Arksey & O'Malley (2005), with additional recommendations taken from Grant & Booth (2009). Arksey & O'Malley (2005) set out a methodological framework that is based on 5 stages:

- **Stage 1**: identifying the research question
- **Stage 2**: identifying the relevant studies
- **Stage 3**: study selection
- **Stage 4**: charting the data
- **Stage 5**: collating, summarizing, and reporting the results

There are four reasons to conduct a scoping review: (1) to examine the extent and nature of research activity, (2) to determine the value of undertaking a systematic review, (3) to summarize and disseminate research findings, and (4) to identify research gaps (Arksey & O'Malley, 2005). This paper intends to explore the field of anatomy education and determine if there is consensus in the literature as to whether there are significant differences in educating various student populations. Additionally, this paper will determine if there is a sufficiently large gap in the literature that researchers should endeavour to bridge with additional study.

Grant & Booth (2009) state that a scoping review provides a preliminary assessment of the size and scope of available research literature. This type of review typically characterizes the quality and quantity of literature (Grant & Booth, 2009). By examining all types of anatomy education across multiple domains of student education, it is expected that this scoping review will accurately assess the quality and quantity of the literature surrounding the instruction of anatomy.

**Identifying the Research Question**

This scoping review sets out to establish if there are clear differences in the anatomy curriculum for students studying in various educational contexts, and if so, what those differences are. The literature on anatomy education is often based on
anecdotal evidence rather than rigorous research findings (Craig et al., 2010; Vorstenbosch, Bolhuis, van Kuppeveld, Kooloos, & Laan, 2011). This scoping review aims to objectively examine the literature to obtain an unbiased understanding of current trends and topics in anatomy education, and to determine which methods are available and commonly used by instructors and professors.

There are many studies in the literature regarding educational interventions for anatomy courses. Some articles focus on the current state of anatomy education, some examine different tools and features of effective anatomy education, and others discuss levels of anatomy education required in different domains of clinical practice. There is an absence of literature examining which interventions are best suited for different student populations. In this case, a scoping review is most appropriate, as this research question has not been thoroughly explored in previous research efforts and could serve as a guide to future efforts in the area.

The scope of this paper is limited by several inclusion and exclusion criteria, and is not restricted by the learning tools implemented in the included research. Therefore, a wide variety of teaching methods were included, and should therefore capture the essence of anatomy education from the previous decade.

**Identifying the Relevant Studies**

PubMed, Scopus, and ERIC were all searched using the search phrase “anatomy AND education AND learning,” using titles, abstracts, and keywords to capture relevant articles. These databases were searched up to the 30th April 2019, and the search was limited to a ten year period. This was selected due to the rapid development of educational technology. By limiting the research results to the last ten years, the studies that used technology in their research design would be more refined and mature, and therefore be better suited to compare to other modalities of teaching. It is expected that this will offer a more fair, objective comparison between different learning tools implemented in the anatomy classroom.
The databases were searched because they were believed to contain the most number of relevant articles that could be included in the scoping review. PubMed and Scopus both are primary repositories of articles from the medical community, and ERIC provides articles that focus on educational interventions.

**Study Selection**

All studies captured from database searching were passed through two levels of review. In the first phase of review, articles were first assessed for relevance to the research question, and the titles and abstracts were assessed by the inclusion and exclusion criteria. Arksey & O’Malley (2005) emphasize that this is not a linear process, as early findings can be reshaped by new insights. As such, the criteria were developed *ad-hoc* throughout the first phase. As the body of literature became more familiar, more relevant and specific criteria could be developed. The article selection and analysis was conducted by one reviewer.

During the second phase of review, articles were examined by their full text. They were judged for inclusion or rejection by applying the same criteria. At this point, the inclusion and exclusion criteria had been finalized from the first phase of review. This ensured consistency in the final selection of articles for the scoping review.

An article was included if it:

1) Discussed anatomy curricula in a classroom setting for the study of medicine, dentistry, rehabilitation sciences, or students in their undergraduate degree. A paper would be considered if it examined grade impacts created by the intervention or curriculum change, or gathered student perceptions on an intervention or curriculum change.

2) Had an educational intervention clearly aimed at the targeted student populations.

3) Discussed anatomy curriculum in the context of educational interventions.
An article was excluded on the following criteria:

1) The paper did not include sufficient detail on the curricula or educational intervention being implemented, or targeted clinical rather than educational or classroom settings.

2) The paper did not clearly target a clinical or non-clinical student population delineated in the introduction.

3) The paper focused on the creation, maintenance, or professional-based assessment of a learning tool or testing method, rather than the implementation or impact on student learning outcomes. Reviews and editorials were also eliminated in this criterion, as were discussions of curricular change. Papers that gathered survey responses and opinions from institution members or recent graduates were not included.

4) The papers included an examination of related courses (including physiology, histology, pathohistology, embryology, pathology, genetics, neuroanatomy and neuroscience, biology, biomechanics, etc.).

Furthermore, the search results were limited to a ten year period.

**Charting the Data**

The articles included for review were listed and organized in a table including author names, the article name, and year of publication, and country. A second table tracked the student population targeted by the authors of the paper, the classification of the learning tool according to the categories put forth by Estai and Bunt (2016), the tool or educational intervention used by the study, and the specific body system or region the tool targeted (where applicable). The entry numbers are consistent between each table for reference.

**Collating, Summarizing, and Reporting Results**

All sources included for review were sorted and stored in EndNote (version 9.1.1, Clarivate Analytics, Philadelphia). After all databases were searched, duplicates removed, and inclusion and exclusion criteria applied, the final papers selected for analysis were subjected to a qualitative analysis of the key findings.
Figure 1: Outlining the Article Selection Process. Articles went through several rounds of review. The first assessed for relevance, and articles that were not relevant to the research question were removed. In the second round, articles were judged on both their titles and abstracts. Articles that remained after this round were subject to a full text analysis, and which point the final articles were removed before the remainder were charted for the scoping review. Where an article was rejected on multiple exclusion criteria, it was only counted against the single most relevant criterion.
Results

In total, 157 papers were included for analysis. The authors, title, year, and country of the articles included in the scoping review can be found in Table 1. Information about the student population, intervention used, and body region or system focused on can be found in Table 2.

PubMed returned 710 results, Scopus yielded 594, and ERIC provided 439 papers. In total, 1,743 papers were captured, and after 457 duplicates were accounted for and removed, there were 1,286 papers (Figure 1). This first phase of review had 397 papers removed on the basis of relevance. Another 732 papers were removed pursuant to the four rejection criteria (Figure 2). This left 157 papers for analysis.

Demographic Features

Papers were published from all areas of the world, with a large concentration from the United States (n = 46), Australia (n = 21), the United Kingdom (n = 17), and Canada (n = 10), representing approximately 60% of the total literature included in this review (Figure 6). Beyond this, the publication origin was widely varied, with over half of the countries having only a single article included for review and 80% having 3 or fewer articles. In general, the number of publications that were captured by the search criteria increased year over year (Figure 4).

Distribution of Studies by Body Regions and Systems

More studies examined the body by region (n = 80) (Figure 7) than by system (n = 12) (Figure 8). If a researcher clearly identified a region or system in their study, it was recorded in Table 2 and in Figures 7 and 8. However, if a researcher declared which type of anatomy curricula was employed in their focus group, it was not necessarily considered among the Systems-Based Curricula category offered by Estai and Bunt (2016).

Some teaching methods (such as cadaveric dissection) were more suited to a regional approach to teaching, others (such as computer models and graphics)
were well suited to a systems-based approach. There were also methods that showed no specificity to either regional or systems-based teaching, such as problem based learning and peer teaching.

**Distribution of Studies by Student Population**

**Medical Students**
Medical students were the most frequently targeted student population, representing 72% of the literature (Figure 3). Medical imaging was the most common category explored with medical students (32%), followed by CAI (18%) and cadaveric dissection (16%). Plastination (1.3%) and prosection (3.2%) were the least explored categories among interventions for medical students. An additional 25% of the teaching strategies and modalities used for medical students did not fit the categories offered by Estai and Bunt (2016).

**Dentistry Students**
Dentistry students were included in 6% of the literature (Figure 3). This smaller percentage may be explained by the fact that the anatomy they need to know is limited to a small region of the body. Cadaveric dissection and CAI each represented 23% of the educational interventions used among dental students. Medical imaging (n = 2), plastination (n = 1) and living anatomy (n = 1) were also used in this student population. An additional 23% of the interventions used for dental students did not fit into the categories offered by Estai and Bunt (2016).

**Nursing Students**
Nursing students represented the smallest percent of the literature (4%) (Figure 3). The low percentage of nursing students captured in this scoping review may suggest that anatomy is not viewed as an important component of nursing training. Within the literature focusing on nursing students, 50% did not conform to the categories of Estai and Bunt (2016).
Rehabilitation Sciences Students
Studies with rehabilitation sciences students appeared 7% of the time in the literature, marginally ahead of the number of dentistry-focused studies (Figure 3). Approximately 67% of the literature focused on this population explored the use of CAI. Cadaveric dissection and prosections were also explored in this population, each accounting for approximately 17%.

Undergraduate Students
Only 11% of the included literature was focused on non-professional program, undergraduate students (Figure 3). The remaining 89% of the literature targeted students in healthcare oriented degrees. The majority of the educational interventions targeted at this population were computer-aided learning methods (71%). This is likely due to the ability to implement computer-based resources in large classes in a cost-effective manner. Another two studies examined the use of medical imaging among this student population. Living anatomy and cadaveric dissection each appeared once as an intervention for undergraduate students.

Distribution of Studies by Category
Cadaveric Dissection
Overall, 29 papers (13%) focused on cadaveric dissection as a discrete learning tool (n = 8), or in combination with other educational interventions (n = 21) (Figure 9). Cadaveric dissection has long been regarded as a key component of medical education, most studies around cadavers have focused on medical students (Mc Garvey, Hickey, & Conroy, 2015). This was true in this scoping review: 77% of the articles that used cadaveric dissection focused on medical students. Nursing and undergraduates were the least targeted student groups for cadaveric dissection, with only 3% of the literature each. The combination of all categories using cadaveric specimens (dissection, prosection, and plastination) represented almost 60% of all literature included in the scoping review. This indicates that the use of cadaveric material is still effective and important, even as teaching methods continue to develop and evolve. Across the ten year period examined by this
scoping review, the rate of publication focused on cadaveric dissection remained fairly constant, except for one spike in the number of publications in 2016 (Figure 5).

**Prosections**
Eight papers (4%) examined the educational impact of prosections on student learning and comprehension (Figure 9). Prosection never appeared in isolation as its own learning tool, and was always accompanied by another intervention. These included cadaveric dissection, plastination, computer-based resources, and medical imaging. Medical students were the most common student population to be targeted by prosections (63%), even though prosections and plastination each were the least common form of intervention for medical students. Like cadaveric dissection, the number of publications per year focusing on prosections was low, and never exceeded more than three papers each year (Figure 5).

**Plastination**
Medical students again represented the most frequently targeted group (50%) for interventions that used plastination; nursing students and dentistry students represented the other half of the student populations targeted by plastination-based interventions. As an educational intervention, it appeared on its own half of the time, and was combined with another teaching strategy the remaining half of the time it appeared in the literature. There was no discernible pattern in the number of times per year a publication included it as an educational intervention (Figure 5).

**Computer-Aided Learning**
Among the categories offered by Estai and Bunt (2016), computer-aided learning was second only to medical imaging and captured 21% of the literature obtained in the scoping process (Figure 9). Computer-aided learning took many forms, and was therefore the most versatile learning tool found in the literature. These included AR (n = 7), VR (n = 4), online learning and forum discussions (n = 10), and the use of mobile devices (n = 2). Computer-aided instruction was the most prevalent form of educational intervention for undergraduate students, and 75% of all educational interventions for medical students involved CAI. Computer-aided instruction saw a
steady increase in the amount of attention it received throughout the research period (Figure 5).

**Medical Imaging**

Medical imaging constituted 24% of the included literature, making it the largest category (Figure 9). It took various forms, such as X-Ray (n = 6), Magnetic Resonance Imaging (MRI) (n = 4), and Computed Tomography (CT) (n = 15). Ultrasound was the most common form of medical imaging (n = 17, 40%). Along with CAI, the use of medical imaging increased across the ten year period of this scoping review (Figure 5).

**Living Anatomy**

Living anatomy constituted only 3% of the overall literature captured (Figure 9), and showed no consistency when analyzed by the number of publications per year focusing on this modality (Figure 5). It was mainly implemented as body painting (50%) for medical students to help teach surface anatomy. The other half of the literature in this domain used ultrasonography on student peers to teach the relation between surface features and deeper anatomy. This subset of the literature is included in the Living Anatomy category for its use of real people (students), whereas other studies use medical imaging on cadaveric specimens.

**Lecture-Based Learning**

Lecture-based learning was not widely explored in the literature. This may be due to its existing relationship with anatomy that has extended over the previous four centuries. Only a single paper addressed this category, exploring how to make lectures more interactive for medical students.

**Integrated Curricula**

The literature that discussed integrated curricula was limited to only one paper. This was expected, since this category is only relevant to medical students and the nature of this topic mainly focuses on the structure of curricula, not necessarily the ways in which anatomy in particular is taught to students. Discussion of curricular
changes or structure with no clear educational intervention was excluded from the scoping review. Therefore, it may be underrepresented in this document, as it lay beyond the purview of the scoping review.

**System-Based Curricula**
Although a mix of system-based and regional-based anatomy studies were encountered in the literature, the number of papers addressing this category were scarce. This is likely because of the nature of the research question and the inclusion and exclusion criteria.

**Unassigned**
Interestingly, 33% of the papers included for review used learning tools that could not be captured by one of the categories laid out by Estai and Bunt (2016) (Figure 9). This provides the basis and justification for re-categorizing the types of anatomy instruction used to teach students, and will be explored further in the discussion section.

The most common uncategorized learning tools included problem-based learning (PBL) \(n = 5\), case-based learning (CBL) \(n = 4\), inquiry-based learning (IBL) \(n = 2\) and team-based learning (TBL) \(n = 5\). Furthermore, peer teaching \(n = 5\) and 3D printed (3Dp) models \(n = 10\) represented large areas of research literature that did not fit neatly into one of the categories.
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Country</th>
<th>Student Population</th>
<th>Classification</th>
<th>Tool Used</th>
<th>Specified Region / System</th>
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<td>Problem-based learning</td>
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<td>Head and neck</td>
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<td>Alfalah et al.</td>
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<td>Jordan</td>
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<td>Computer-aided instruction</td>
<td>Virtual reality</td>
<td>Heart</td>
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<td>Syria</td>
<td>Medicine</td>
<td>Drawing</td>
<td></td>
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<td>2018</td>
<td>India</td>
<td>Nursing Medicine</td>
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<td>Computer-aided instruction</td>
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<td>Medicine</td>
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<td>Ultrasound Prosection</td>
<td>Heart</td>
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<td>Torres et al.</td>
<td>2016</td>
<td>Poland</td>
<td>Medicine</td>
<td>Medical imaging</td>
<td>Ultrasound CT scans</td>
<td>Abdomen Pelvis</td>
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<tr>
<td>Van Nuland &amp; Rogers</td>
<td>2017</td>
<td>Canada</td>
<td>Undergrad</td>
<td>Computer-aided instruction</td>
<td>Computer aided learning</td>
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<td>Wang et al.</td>
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<td>China</td>
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<td>Problem-based learning</td>
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<td>Waters et al.</td>
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<td></td>
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<tr>
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<td>Undergrad</td>
<td></td>
<td>Animal-based dissection</td>
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<tr>
<td>Williams et al.</td>
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<td>United States</td>
<td>Medicine</td>
<td></td>
<td>Clay modeling</td>
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<tr>
<td>Wright</td>
<td>2012</td>
<td>United States</td>
<td>Undergrad</td>
<td></td>
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</table>
The number of papers rejected on each category in each of the two rounds are represented above. The lower, dark blue region represents the papers that were rejected on the basis of their titles and abstracts. The lighter blue region represents the papers that were rejected after a full text review. The majority of papers (60%) were removed on the final two rejection criteria because of the nature of the learning tool discussed in the paper, or the course being examined was not a purely anatomy course and contained other subjects like embryology and physiology.
Figure 3: Proportion of Student Population
Medical students accounted for nearly three quarters of the total student population targeted. In seven articles (6%), medical students were combined with other student populations for the purposes of the educational intervention being explored. The remaining 115 articles that included medical students focused solely on medical students in isolation from other student populations. If a paper included a target intervention for multiple student populations, each student population was considered separately from the others.
Figure 4: Total Number of Sources by Year
The total number of articles was charted by year of publication, and a trend line applied. An upward trend in the literature included for the scoping review suggests increased interest from scholars.
* The value for publications in 2019 was estimated based on the number of publications from the first four months of the year (the cutoff for database searching was 30th April, 2019).
Figure 5: Trends Across Educational Interventions by Year

The year of publication of each study was matched to the categories offered by Estai and Bunt (2016) to examine the trends of publications year over year in each category. Cadaveric dissection remained constant throughout the scoping review period, except for one increase in 2016. Medical imaging and CAI both saw steady increases in the amount of attention they received in the captured research articles.
Figure 6: Total Number of Sources by Country

The top four countries of publication comprised 60% of the articles captured by the scoping review. Over 80% of the countries listed had three or fewer references, 56% had only one paper captured by the scoping review.
Figure 7: Body Regions Targeted in Literature
Eighty papers discussed the use of an educational intervention in the context of a regional-based anatomy course, and the different regions of the body showed a more balanced distribution than that of the systems-based approach.
Only eight papers implemented an educational intervention in a clearly system-based curriculum. The high prevalence of the musculoskeletal system may correspond to it receiving more attention in the anatomy curricula, or may relate to the relative difficulty of the system compared to others. In some instances, multiple systems were targeted by the same intervention.
Table 2. Cross Referencing Educational Tools by Student Population

<table>
<thead>
<tr>
<th></th>
<th>Medicine</th>
<th>Nursing</th>
<th>Undergraduate</th>
<th>Rehab</th>
<th>Dentistry</th>
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<tr>
<td>Cadaveric dissection</td>
<td>24</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Prosections</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
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<tr>
<td>Plastination</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<tr>
<td>CAI</td>
<td>28</td>
<td>0</td>
<td>12</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Medical Imaging</td>
<td>50</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Living Anatomy</td>
<td>6</td>
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<tr>
<td>Lecture-Based Learning</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>System-Based Learning</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

Multiple interventions per student population were used in some studies. This table does not include interventions with unassigned categories. The Integrated Curricula category offered by Estai and Bunt (2016) is not included in this table because of its specificity to medical student education.
Figure 9: Percentage of Category
Medical imaging, CAI, and cadaveric dissection were the largest categories represented in the literature. Plastination, living anatomy, prosections, system-based curricula, and integrated curricula represented approximately one-tenth of the included literature. The remaining literature could not be sorted into one of the categories and were therefore classified as “unassigned.”

* Integrated curricula, system-based curricula, and lecture based learning were not included in the chart.
Discussion

Based on the growing body of literature around anatomy education, one would expect to see significant changes in anatomy education (Vorstenbosch et al., 2011). However, it is clear from this review that most of the literature is focused on teaching anatomy to professional students, mostly medical students.

Cadaveric dissection seems to remain the primary teaching method for anatomy, as it has in the last four centuries. Learning anatomy through the use of human cadavers is a complex learning experience, and has aspects that are not easy to quantify or objectively evaluate (Winkelmann, 2007). The use of cadaveric material (dissection, prosection, and plastination) as an educational tool represented almost two-thirds of the included literature. What is less clear is whether or not it will remain the highest standard of anatomy education. Despite the apparent quality and efficacy of using cadavers to teach anatomy, their use is still on the decline because of other pressures such as budget cuts, donor shortages, and lack of staff.

While there was a consistent number of publications surrounding the topic of cadaveric dissection as an educational intervention, a number of publications discussed changes in curricula which phased out cadaver-based instruction. In the face of rapidly developing alternative teaching strategies, more attention is being given to CAI, and the results of this scoping review suggest that as cadaveric dissection continues to be subjected to increased budget and resource restrictions, CAI will likely take its place.

Within the field of anatomy education, commercial e-learning tools have capitalized on the assumption that new technologies are at least as effective as traditional methods, and their implementation into anatomy curricula has outpaced objective evidence regarding their effectiveness (Van Nuland & Rogers, 2017). When implementing technology into the classroom setting, it is imperative that pedagogy precede technology (Hanna, 2014). Generally, these new teaching methods and pedagogies are aimed at reaching larger class sizes with fewer contact hours and resources to do so. Anatomy educators must maximize the information transferred
to students with limited resources, while promoting an accurate, three-dimensional understanding of the human body (Lewis, Sagmeister, Miller, Boissaud-Cooke, & Abrahams, 2016). Time constraints are just one factor impacting the decision to use different teaching modalities, others include staff requirements, costs, educational impact, and student acceptance (Griksaitis et al., 2012). Therefore, many of the newer teaching strategies are created with efficiency and expediency in mind. For this reason, CAI approaches to learning anatomy may have an inherent advantages over other teaching methods.

Some ponder whether or not continual budget and resource restrictions will eventually phase out cadaveric dissection from the anatomy curriculum (Pawlina & Lachman, 2004). If this does become the case, it is contemplated whether or not an anatomy course can fulfill its objectives if dissection is no longer offered to students (Granger, 2004). The results of this scoping review suggest that the loss of cadaveric dissection would only negatively affect a small number of students whose careers will demand the most amount of anatomy knowledge, such as future surgeons.

Many scholars believe that a good understanding of anatomy depends upon learning concepts and managing information for solving problems, rather than just memorization (Johnson et al., 2012). The acquisition of anatomical knowledge is a complex process, and is therefore difficult to study objectively (Winkelmann, 2007). Anatomy learning goes through a process of learning, forgetting, restructuring, and applying (Smith & Mathias, 2011). To master anatomy, one must be able to understand three dimensional relationships (Bareither et al., 2013). Learning spatial relationships in anatomy is a difficult feat (Miller, 2000). Students must learn orientation, location, and structural dimension, and retain that information (Bareither et al., 2013).

Learning theory dictates that recall is promoted by learning concepts in the context that they will be used (Rizzolo et al., 2006). The context in which most anatomy knowledge will be employed is in a clinical, patient-focused setting. Clinical
relevance aids anatomy learning (Dusseau et al., 2008). This may partially explain the increased use of medical imaging to instruct students in anatomy, since it represents a tangible link between anatomy that is learned in a class setting and the way it is often presented in professional practice. The growth in medical imaging and minimally invasive surgical techniques requires a sound understanding of anatomy in three dimensions (Knobe et al., 2012). Therefore, teaching students anatomy in a similar manner as that encountered in clinical practice improves patient outcomes and makes anatomy more relevant to students.

Overall, the types of anatomy education modalities put forth by Estai and Bunt (2016) represented the majority of the literature, except for the 33% of the educational approaches that could not be classified (Figure 9). Each category is discussed in the following sections.

**Cadaveric Dissection**

Cadaveric dissection was found to improve student attention (Aversi-Ferreira, do Nascimento, Vera, & Lucchese, 2010) and learning (Aversi-Ferreira et al., 2010; Burgess & Ramsey-Stewart, 2015; Marshak, Oakes, Hsieh, Chuang, & Cleary, 2015; ten Brinke et al., 2014). Students have been found to perform better on anatomy examination questions pertaining to regions they have actively dissected (Pizzimenti et al., 2016), though the effect might be smaller than widely believed (Marshak et al., 2015).

Cadaveric dissection can improve practical skills, as well as anatomy knowledge (Larkin & McAndrew, 2013). It can also contribute to professional skills. The chance to experience death in a controlled environment is an important learning opportunity for students offered by cadaver labs (Mc Garvey et al., 2015). This effect is valuable for any healthcare professional student, and has been demonstrated with nursing student populations as well (Mc Garvey et al., 2015).

Many scholars still argue for the importance of cadaveric dissection in anatomy curricula (Aversi-Ferreira et al., 2010; Pais et al., 2017; Ramsey-Stewart et al.,
46

2010), in both undergraduate and graduate contexts (Barton, Williams, Halle, & McGrew, 2018). However, as the medical curriculum in particular continues to evolve, cadaveric dissection is reduced or removed altogether (Bohl, Francois, & Gest, 2011). Only a few studies included in the scoping review examined cadaveric dissection in isolation from other teaching modalities. Many of the studies that included cadaveric dissection aimed to link it with medical imaging or CAI to further augment its utility. These studies often compared the alternative method to cadaveric dissection, seeking to understand if it could one day replace cadaveric dissection altogether.

Some papers discuss alternatives to anatomy dissection. For example, 3D printing of anatomical structures provides a valuable adjunct to handling cadaveric material related to the heart (Lim, Loo, Goldie, Adams, & McMenamin, 2016) and lower limb (O’Reilly et al., 2016). Animal-based dissections appeared twice in the literature included for review (Musumeci et al., 2014; Waters, Van Meter, Perrotti, Drogo, & Cyr, 2011). In both instances, they served as a viable alternative for human cadaveric dissection. However, it was not recommended that animal-based models replace cadaver labs (Musumeci et al., 2014). Nevertheless, animal dissections have merit.

Small group learning that occurs in the cadaver lab, complemented by digital web based learning, has been found to be a pragmatic and cost effective way to improve anatomy learning for students (Thomas, Denham, & Dinolfo, 2011). Further use of combined methods such as this may help make cadaveric dissection a more appealing method to teachers.

Teaching anatomy to large numbers of students in a dissection lab requires a multitude of skilled instructors (Horneffer et al., 2016), as well as specialized equipment and embalming tools. This makes it one of the most resource intensive teaching strategies available to instructors. It is also very technical and demanding. With novice dissectors, some structures can become disfigured, thereby eliminating or significantly reducing the ability for a student to appreciate those structures
(Carter et al., 2017). So while it is regarded as one of the best teaching methods for anatomy, cadaveric dissection is not a flawless modality and is perhaps not suitable for all anatomical education environments.

**Prosections**

Williams and colleagues (2019) found that the use of prosections was better suited to learning anatomy of the hand and foot rather than dissection of those regions. For physical and occupational therapy students, neither actual dissection or faculty led demonstration proved superior to the other (Kinirons, Reddin, & Maguffin, 2018). By determining which regions of the body may best be learned from prosections rather than dissection may alleviate resource and time constraints of full body cadaveric dissection (Williams et al., 2019), thereby retaining the place of cadaveric material use in anatomy education with increasing limitations surrounding it.

When prosection and dissection were compared against each other, students viewed both learning experiences as positive and valuable (Peeler et al., 2018). Unfortunately, prosection demonstrations may deprive students the hands on experience that cadaveric dissection offers and that kinaesthetic learners thrive on for their learning (Carter et al., 2017). In this regard, it may not be as effective of a learning tool than cadaveric dissection, but it does not require the same technical skills of the learner that the process of dissection demands.

**Plastination**

Medical schools are replacing cadaveric dissection labs with prosected materials, plastinated prosections, plastic models, imaging, and digital models (Mogali et al., 2018). Compared to prosections and dissections, plastinated specimens offer increased strength and longevity, and no odours (James, Chapman, Dhukaram, Wellings, & Abrahams, 2018). These specimens will retain their original structure and can be handled safely (James et al., 2018). These features make plastination a promising technique for teachers, as they are less maintenance and can be used with more students over a longer period of time than either dissection or prosection.
Similar to prosections, the educational value of plastination may depend on the region of the body being explored or taught. For example, using plastinated specimens sliced along a sagittal plane is useful for teaching anatomy of the foot and ankle, and provides a connection between anatomy and radiology (James et al., 2018). It is suggested that plastination can be a successful replacement for cadaveric dissection (Baker, Slott, Terracio, & Cunningham, 2013), but this claim may require more support in the literature before it can be widely accepted. As cadaveric dissection is used less often, plastinated specimens may eventually become the only avenue for student interaction with cadaveric material, but this would likely be caused by restricted resources rather than educational merit.

**Computer-Aided Instruction**

Students have generated a demand for academic material to be delivered through electronic mobile devices, not just through traditional methods (Stewart & Choudhury, 2015). There is a huge potential for the use of these novel technologies in anatomy education (Alfalah et al., 2018).

The benefits of CAI may be specific to the body system or region being taught. For example, a high fidelity model of the larynx offered no benefit for long term retention over a low fidelity model (Fritz et al., 2011), and a 3D model of hepatobiliary anatomy neither enhanced nor inhibited student learning compared to a more traditional textbook approach (Keedy et al., 2011).

**Augmented Reality and Virtual Reality**

Both Virtual Reality (VR) and Augmented reality (AR) have been supported by the literature for the purposes of teaching anatomy (e.g., Bork et al., 2019; Kelly et al., 2018; Moro, Stromberga, Raikos, & Stirling, 2017; Siqueira Da Silva, Klein, & Brandao, 2017). They can increase spatial understanding, particularly in students with low spatial ability (Bork et al., 2019), enhance student learning experiences (Kelly et al., 2018), and increase student engagement (Moro et al., 2017).
Students who used VR to study heart anatomy found it to be highly satisfying compared to traditional methods (Alfalah et al., 2018). A similar study found that VR was an immersive and intuitive experience for students to appreciate the structures of the heart, and was able to increase student performance (Maresky et al., 2019). Similar results were seen in a study where VR was used to teach forearm anatomy, but the authors caution against it replacing traditional methods (Codd & Choudhury, 2011). Augmented Reality allows for student-centred learning and motivates students to learn anatomy with an appreciation for its three dimensional nature (Kugelmann et al., 2018). Thomas and colleagues (2010) used AR technology alongside cadaveric dissection to improve student understanding of the ventricular system of the brain, finding it to be a useful adjunct for students.

The future of anatomy education could be based on AR (Ferrer-Torregrosa et al., 2015). Some authors argue that AR could replace the use of two dimensional atlases (Siqueira Da Silva et al., 2017). Likewise, as VR becomes more cost effective, it may become a more enticing teaching strategy for instructors (Maresky et al., 2019).

**Mobile Devices**

Another form of CAI is mobile learning. The use of mobile technologies among students in learning contexts is growing to the point of ubiquity, thereby forcing educators to reexamine its merits (Lazarus, Sookrajh, & Satyapal, 2017). The use of tablet devices was found to have a positive effect on learning outcomes (Lazarus et al., 2017; Wilkinson & Barter, 2015), as well as student attendance (Wilkinson & Barter, 2015). Mobile devices such as tablets can also enhance and facilitate group learning (Wilkinson & Barter, 2015). The use of mobile devices also works well when exploring medical imaging. For example, the use of iPads to view CT imaging was met with positive reception from students (Murakami et al., 2014).
Blended Learning, Flipped Classrooms, and Online Learning

An alternative to pure lecture based learning is blended learning (Estai & Bunt, 2016). This method utilizes the combination of traditional face to face lectures and online learning (Kharb & Samanta, 2016). The use of blended learning is well suited to anatomy courses (Green & Whitburn, 2016). Blended learning provides students the best possible learning and teaching experiences while simultaneously supporting teachers in their role as facilitators. (Kharb & Samanta, 2016). The use of blended learning can help instructors overcome the time constraints of a typical classroom (Kharb & Samanta, 2016). The overarching goal of a flipped classroom or blended learning is to achieve a more student-centred learning environment through active and collaborative learning (Park & Howell, 2015). The use of online resources and blended learning is able to reach students with different learning styles, background knowledge, and interest (Wright, 2012). However, the efficacy of this type of learning tool may be limited by the self-discipline of the student (Mathiowetz, Yu, & Quake-Rapp, 2016).

Student use of online forum discussion was found to be associated with higher academic achievement (Green, Farchione, Hughes, & Chan, 2014; Green & Hughes, 2013; Green & Whitburn, 2016; Wright, 2012). The use of online forum discussion may encourage higher level learning outcomes (Green & Hughes, 2013). The time taken to develop and maintain online course content is worthwhile, offers improved student learning outcomes, and does not negatively impact student engagement or satisfaction (Green & Whitburn, 2016).

The use of online materials to aid anatomy instruction is intriguing. It is a resource that is readily available to students and is easily managed by teaching staff, but its effectiveness depends on the motivation of the student to access those materials. Attardi and colleagues (2016) found that students appreciated the control and flexibility afforded to them through the use of online materials. However, students still preferred face to face instruction, as they found it more engaging and had fewer distractions (Attardi et al., 2016). Blended learning should not be a simple matter of combining methodologies without clear pedagogical goals (Park & Howell, 2015).
is important for instructors to maintain a clear set of learning outcomes for their students, regardless of the teaching modalities used. Finally, the use of online learning tools deprive students the hands-on experience typically associated with learning anatomy.

**Three Dimensional Computer Models and Graphics**

Three dimensional visualization techniques and animations are supported by the literature (e.g., Fleagle, Borcherding, Harris, & Hoffmann, 2018; Hoyek, Collet, Di Rienzo, De Almeida, & Guillot, 2014) and appreciated by students (Mitrousias et al., 2018). Three dimensional animations facilitate the comprehension of spatially demanding anatomical knowledge (Hoyek et al., 2014). Compared to prosections, 3D software is more accessible and requires fewer resources (Mitrousias et al., 2018).

Three dimensional computer graphics can have a positive impact on student learning when properly integrated into conventional curricula (Battulga, Konishi, Tamura, & Moriguchi, 2012). For example, three dimensional visualizations of hepatobiliary anatomy were compared to 3Dp material, and each had the same effect on student learning and satisfaction (Kong et al., 2016).

**Audiovisual Materials**

The use of digital audiovisual resources to prepare students for dissection was found to significantly improve student examination results (Choi-Lundberg et al., 2016) and student satisfaction (Ahmad et al., 2016). Audiovisual materials are also typically well-received by students (Topping, 2014). Even Youtube has found a place in anatomy education, owing to the platform’s popularity among students (Jaffar, 2012).

**Digital Textbooks**

Digital textbooks are effective in terms of usability, student satisfaction, and content (Stirling & Birt, 2014). They can be used alongside traditional methods of anatomy
teaching to enhance and promote deeper learning (Stewart & Choudhury, 2015; Stirling & Birt, 2014), and reduce teacher loads (Stirling & Birt, 2014).

iBooks, a form of digital textbook, was a successful resource for students, as it helped them learn content in a fun and interactive manner (Stewart & Choudhury, 2015). Digital textbooks might not be able to outperform traditional methods, but they are well received by students for their user experience (Stirling & Birt, 2014). Therefore, they work well as an adjunct or supplement to compliment other forms of anatomy teaching.

**Medical Imaging**

Medical imaging is becoming increasingly relevant in today’s healthcare system (Bork et al., 2019). Therefore, it follows that the findings of the scoping review suggest medical imaging is becoming more prevalent. This was reflected in the increasing attention given to medical imaging year over year (Figure 5). Along with CAI, medical imaging was one of the only categories to show an increased prevalence in the included literature over the ten year period of this scoping review.

A strong working knowledge of anatomy is critical for students to learn radiology (Arya, Morrison, Zumwalt, & Shaffer, 2013). Integration of anatomy and radiology is a useful and valuable addition to the standard anatomy course (Dettmer et al., 2013; Machado, Barbosa, & Ferreira, 2013). The use of imaging techniques represents a viable contribution towards anatomy instruction (Kolossvary et al., 2017). The early integration of medical imaging may facilitate understanding radiology in later years of study (Buenting et al., 2016). Teaching radiology with anatomy can provide students with new perspectives in anatomy while simultaneously making them more aware of the clinical importance of anatomy (Dettmer et al., 2013). Demonstration of anatomy via imaging tools helps promote an appreciation of the clinical relevance of anatomy (Griksaitis et al., 2012; Ivanusic et al., 2010).
X-Rays, CTs, and MRIs

The use of an online medical imaging resource is favourably received by students (Marker, Bansal, Juluru, & Magid, 2010; Marker, Juluru, Long, & Magid, 2012). Small group, hands-on teaching model for radiological anatomy was perceived as useful for students and teachers alike (Torres et al., 2016). Images from X-Rays, CT scans, and MRI scans are often included in didactic lectures, but simply including these images in lectures does not make the imaging tools accessible to students (Carter et al., 2017).

One paper suggested that teaching anatomy solely with CT images is feasible (Kolossvary et al., 2017). However, others argue that medical imaging may not be able to completely replace cadaveric dissection. For example, Bohl and colleagues (2011) found that CT images were not a suitable substitute for cadaveric dissection of the heart.

Ultrasonography

Like CTs and MRIs, ultrasound has become increasingly important in clinical contexts (Smith, Kendall, & Royer, 2018b). It has been shown to be beneficial to undergraduate, medical, and dental students alike (Ivanusic et al., 2010). What is particularly beneficial about learning anatomy with ultrasonography is the connection it applies between surface anatomy landmarks and associated deeper structures (Carter, Hocum, Pellicer, Patel, & Benninger, 2016).

Medical students feel it is practical and feasible to include ultrasound as a teaching tool in conjunction with traditional teaching methods (Brown et al., 2012a). They perceive it as valuable in understanding anatomy and learning physical exam skills (Rempell et al., 2016). Dental students also show satisfaction in the implementation of ultrasound in their anatomy curriculum, as it can provide a better understanding of maxillofacial anatomy (Kondrashova, De Wan, Briones, & Kondrashov, 2017).

The use of ultrasound to teach cardiac anatomy was found to be equivalent in quality to the use of cadaveric prosections and plastic models (Canty, Hayes, Story,
& Royse, 2015). The use of ultrasound may facilitate the learning of structural anatomy, and contribute to the interpretation of CT and MRI imaging (Carter et al., 2017). While students may view ultrasonography positively, it may not be enough to bridge the gap between traditional methods and clinical application (Sweetman, Crawford, Hird, & Fear, 2013). Simply including ultrasonography in an anatomy curriculum is not enough to make the course more clinically relevant, so care must be taken to ensure that students are properly trained in its use and how it facilitates patient-care in a clinical setting.

Some scholars argue that training anatomists to teach anatomy with ultrasonography could be useful in training future physicians (Jurjus et al., 2014). Further arguments exist that ultrasound should be an essential component of future physician training (Serrao et al., 2017).

**Medical Imaging and Cadavers**

In some cases, cadaveric dissection was preceded by CT scans, such that both aspects could be used by the students (Bohl et al., 2011; Buenting et al., 2016; Lufler et al., 2010; Murakami et al., 2014). Moreover, CT images were directly compared to prosections and found to be of equal educational value (Kollossvary et al., 2017). This is also seen in studies where ultrasound training is done on cadavers used for dissection (e.g., Abed Rabbo, Garrigues, Lefevre, & Seizeur, 2016) and prosection (Griksaitis et al., 2012). Finally, X-Ray images on cadavers are perceived as beneficial by medical students (Kotzé, Mole, & Greyling, 2012).

**Living Anatomy**

Body painting was a common teaching method for the living anatomy category. With this technique, different structures such as bone, muscle, vessels, and nerves are painted on to a living body (Jariyapong, Punsawad, Bunratsami, & Kongthong, 2016). The main advantage of body painting seems to lie in the creation of memorable and vivid experiences for students (Finn & McLachlan, 2010).
It is regarded as highly motivating for students, and is useful in large group settings (Finn & McLachlan, 2010). The use of body painting allows students to simultaneously learn anatomy and practice their professional skills (Finn & McLachlan, 2010). For example, it helps train students on how to respectfully work with patients in sensitive areas of their body, and provides deeper understanding to how clinical work on the surface of the body correlates to deeper structures (such as using a stethoscope to listen to the heart and lungs).

**Lecture-Based Learning**

Alongside cadaveric dissection, lectures have been a key component of anatomy education (Vázquez et al., 2007). Some argue that no matter which methods are used to provide lectures to students, the impact of the learning session is highly dependent on the lecturer (Jarral et al., 2017). Changes in classroom structure have been driven by pedagogy and resources (Estai & Bunt, 2016). Scholars and educators continue to look beyond the lecture hall to make learning more interactive, engaging, and impactful for students.

**Integrated Curricula**

Integrated curricula, where basic sciences and clinical medicine are taught together, have been in use for the last four decades (Pan, Cheng, Zhou, Li, & Yang, 2017). Integrated curricula have been shown to improve the analytical abilities of medical students (Pan et al., 2017). Longitudinal integration of medical imaging in anatomy education may improve student confidence in understanding imaging modalities and their clinical importance (Moscova, Bryce, Sindhusake, & Young, 2015).

**System-Based Curricula**

Learning anatomy by system is viewed as easier than a region based approach, since learners can master one system at a time (Estai & Bunt, 2016). Furthermore, students can better retain factual information and can more easily relate that information to clinical practice (Estai & Bunt, 2016).
Alternative Teaching Methods

Three Dimensional Models

Three dimensional models can serve as an alternative to cadaveric dissection or prosection (Zumwalt, Lufler, Monteiro, & Shaffer, 2010), or as a supplement to cadaver-based curricula (Lim et al., 2016). Unlike cadaveric specimens, 3D teaching materials can be amassed, stored, and kept on a more permanent basis (Brown, Hamilton, & Denison, 2012b), which makes them more cost effective.

Dynamic visualization of three dimensional models may be a solution to the challenges of static, traditional teaching methods (Berney, Bétrancourt, Molinari, & Hoyek, 2015), such as textbooks and lectures. Stereoscopic representations of three dimensional models provide better representation of structural relationships than two dimensional models of the same material (Cui, Wilson, Rockhold, Lehman, & Lynch, 2017). Three dimensional stereoscopic models may improve anatomy performance, in particular for students with lower spatial ability (Cui et al., 2017).

Three Dimensional Printed Models

3D printing (3Dp) is an innovative method of teaching anatomy (Lim et al., 2016) and a powerful teaching aid (Yi et al., 2019). Three dimensional printed models offer several benefits over cadaveric dissection, such as cost, ethics, and hygiene (Chen et al., 2017). They are an excellent learning tool, and serve as a valuable adjunct to cadaveric dissection or plastinated prosections (Mogali et al., 2018). However, students feel that 3Dp models are not as realistic as plastinated prosection (Mogali et al., 2018; Smith, Tollemache, Covill, & Johnston, 2018a). Therefore, they may not be able to completely replace cadaveric materials. Developing reliable methods for replicating the human body for the purposes of anatomy instruction is important (Cai, Rajendran, Bay, Lee, & Yen, 2018), and therefore 3Dp models are a valuable, emerging teaching tool.

Three dimensional models, particularly 3Dp models, are often derived from patient CT imaging data, such that they reflect real patient anatomy (e.g., Smith et al.,
Three dimensional printed bone models may facilitate understanding of bone anatomy in complex sites, and may improve student satisfaction (Wu et al., 2018). Functional 3Dp modelling of joints can improve spatial anatomical understanding (Cai et al., 2018). The use of 3Dp models used to teach cardiac anatomy were found to significantly improve exam scores (Lim et al., 2016). Three dimensional printed skulls were helpful to students, compared to cadaveric skulls and atlases (Chen et al., 2017). They can elucidate complicated structures, like the ventricles of the brain (Yi et al., 2019). They were also shown to aid students in understanding complex pathologies such as vertebral fractures (Li et al., 2015).

Clay Modelling
Clay modelling is increasingly being used to teach students (Kooloos, Schepens-Franke, Bergman, Donders, & Vorstenbosch, 2014). Students modelling anatomy with clay earned higher exams scores compared to students doing cat dissections (Waters et al., 2011). It is low cost, and involves kinaesthetic approach to learning (Kooloos et al., 2014).

Inter-Professional Learning
Anatomy is well suited to inter-professional learning approaches, as it is essential to many health care professionals (Herrmann, Woermann, & Schlegel, 2015) and can be easily related between different professional tracks (Sytsma et al., 2015). An efficient healthcare system relies on key competencies such as teamwork and collaboration for safe patient care (Herrmann et al., 2015). Students in healthcare professions often receive adequate education for their own practice, but are left in need of more preparation for inter-professional collaboration (Herrmann et al., 2015). This provides another link between anatomy and patient outcomes, as well as professional competencies.

Inter-professional learning can have both immediate and long lasting effects on learners, and contributes to professional collaboration, teamwork, and communication (Sytsma et al., 2015). Using inter-professional education within the
anatomy classroom encourages collaboration and reinforces concepts that students learn in their respective disciplines (Sytsma et al., 2015).

**Case-Based Learning**
Case-based learning (CBL) resources are a valuable adjunct to anatomy instruction (Holland & Pawlikowska, 2018). It is effective in teaching gross anatomy in a manner that is more interesting, integrated, and relevant (Jarral et al., 2017). Case-based learning has been demonstrated to improve academic test scores and better prepare students for clinical practice, and is welcomed by students (Parmar & Rathinam, 2011). While online CBL resources require considerable effort and time from staff in creating them, their use with subsequent student cohorts requires much less work and only minimal maintenance (Holland & Pawlikowska, 2018).

Case-based learning can help link theory to practice (Jarral et al., 2017). Anatomy seen in clinical settings often appear in the context of a patient case, and CBL prepares students on how to work through a case or problem in a guided environment.

**Problem-Based Learning**
Problem-based learning (PBL) curricula are centred around the idea that the student is the central player, learning occurs in group discussions, and problems form the basis of teaching materials (Wang et al., 2010). The learning process in a PBL curriculum is more personal and engaging, improves learning efficiency, stimulates learning interest, and inspires students’ initiative (Wang et al., 2010). In this regard, it is similar to CBL and team-based learning.

Problem-based learning has been shown to provide a significant improvement in student knowledge and confidence (Al-Madi, Celur, & Nasim, 2018). It promotes life-long learning by changing the aim of teaching from the delivery of professional knowledge to cultivation of the ability to learn (Wang et al., 2010). Problem-based learning can be a potent tool for long term knowledge retention and confidence (Al-Madi et al., 2018), and may be more beneficial than traditional methods of teaching.
anatomy (Saalu, Abraham, & Aina, 2010). However, PBL alone might not be enough to ensure adequate learning of anatomy (Bergman et al., 2013). The most effective approach to PBL may involve pairing it with more traditional methods to maximize its effectiveness and student achievement of learning outcomes (Saalu et al., 2010).

**Team-Based Learning**

Team based learning (TBL) is a teacher-directed approach that uses the application of knowledge in small group settings (Ghorbani, Karbalay-Doust, & Noorafshan, 2014). Team-based learning combines individual student preparation outside of the classroom with in-class discussion in small groups (Melovitz-Vasan, DeFouw, & Vasan, 2013). It aims to go beyond simply covering course content and instead ensures students use course concepts to solve problems that enhance student learning (Ghorbani et al., 2014). The TBL environment promotes active learning and deeper understanding (Inuwa, 2012).

Team-based learning as an education method results in improved knowledge gain and higher student satisfaction (Ghorbani et al., 2014). Students perceive TBL to be more rewarding and enjoyable than regular lecture-based teaching (Inuwa, 2012). Working in teams can improve student performance compared to working individually (Martinez & Tuesca, 2014; Melovitz-Vasan et al., 2013), and students tend to be more engaged in their learning with TBL, as the team environment facilitates active learning and peer teaching (Melovitz-Vasan et al., 2013). Team-based learning is highly applicable to cadaveric dissection labs, where students often work together dissecting the same body.

**Inquiry-Based Learning**

Inquiry-based learning is defined as a range of strategies that promote student learning through independent investigation of questions, issues, or problems through the process of scientific inquiry (Lee, 2004, as cited in Anstey et al., 2014). It elicits authentic, meaningful learning experiences (Anstey et al., 2014). Students find their learning from IBL relevant and applicable to their exploration of anatomy in a creative and personally meaningful way, and can facilitate student development
and maintenance of intrinsic motivators such as self-regulated learning, autonomy, and responsibility for learning (Anstey, 2017).

**Art and Drawing**
There is a strong association between art and medicine (Bell & Evans, 2014). The use of art to teach anatomy may contribute to observational skills (Bell & Evans, 2014). Drawing before or after dissection of a cadaver positively influences students’ comprehension of anatomy (Alsaid & Bertrand, 2016). The use of screencasts and drawings were well received among students (Greene, 2018) and may enhance learning compared to paper-based resources (Pickering, 2017).

**Games**
Gamification of anatomy education can affect the learning process through altering student motivation, and results in better academic outcomes for student participants (Ang, Chan, Gopal, & Li Shia, 2018). Games may be a particularly effective vehicle for education, owing to their inherently interactive nature (Hill & Nassrallah, 2018). Anatomy games can allow learners to explore their knowledge strengths and deficits (Janssen, Shaw, Goodyear, Kerfoot, & Bryce, 2015). They have demonstrated to be engaging (Hill & Nassrallah, 2018; Janssen et al., 2015) and satisfying (Hill & Nassrallah, 2018); this is especially true when students can work together towards a common goal (Janssen et al., 2015). Furthermore, the introduction of organized competition via games can increase student motivation and academic outcomes (Van Nuland, Roach, Wilson, & Belliveau, 2015).

**Peer Teaching, Peer Tutoring, and Peer-Assisted Learning**
Peer teaching can be a positive and beneficial experience for students (Agius et al., 2018; Bruno et al., 2016; Oakes, Hegedus, Ollerenshaw, Drury, & Ritchie, 2018). The use of peer assisted learning creates a favourable and fear-free learning environment for anatomy students (Horneffer et al., 2016). Peer teaching could be a valuable tool for teaching traditionally difficult health sciences courses to students (Bruno et al., 2016), such as anatomy. Peer teaching can improve educational outcomes while simultaneously managing the increasing demands placed on
faculty members (Agius et al., 2018). Furthermore, the use of this strategy does not necessitate increasing the number of professors or other salaried instructors (Resuehr & Makeeva, 2015), making it an attractive modality for anatomy instructors. The student tutors often receive formal training from instructors before tutoring other students, and tutors are often selected based on good academic standing (Christensen, Schmalz, Challyandra, & Stark, 2018).

Students with lower academic outcomes stand to gain more from peer teaching (Bruno et al., 2016; Hanna, Johnson, & Belliveau, 2015). Conversely, medical students who enrol in peer-teaching programs as teaching assistants gain valuable teaching experience for their future residencies (Resuehr & Makeeva, 2015). Peer tutoring is also useful for cadaveric dissection labs (Christensen et al., 2018; Dickman, Barash, Reis, & Karasik, 2017; Kinirons et al., 2018).

Similarly, near-peer teaching can allow faculties to meet the academic needs of a large number of students (Duran et al., 2012; Resuehr & Makeeva, 2015). Near-peer teaching is a similar approach to peer based learning, where students are taught by their classmates or more senior students, thereby drawing on a similar knowledge-base and set of experiences (Hall, Lewis, Border, & Powell, 2013, as cited in Dickman et al., 2017). It is effective in its ability to facilitate anatomy education in situations with limited resources and fewer staff members responsible for larger class sizes (Pickles et al., 2019). Both the learners and the student co-instructors find the experience of near-peer teaching to be valuable (Naeger, Conrad, Nguyen, Kohi, & Webb, 2013). Given the positive impact of near-peer teaching, it seems appropriate to utilize it in a larger scale to enhance learning experiences (Dickman et al., 2017). The implementation of near-peer teaching programs in anatomy courses is strongly supported (e.g., Agius & Stabile, 2018).

**Self-Directed Learning**

Supported self-directed learning (SDL) approaches can be beneficial for anatomy teaching and lead to improved and deeper understanding of anatomy knowledge (Findlater, Kristmundsdottir, Parson, & Gillingwater, 2012; Serrat et al., 2014). This
has been demonstrated through improved student exam scores (Findlater et al., 2012). Self-directed learning projects are high yield, low cost solutions to teaching anatomy in resource-limited institutions or programs (Serrat et al., 2014). This method can be adapted to accommodate different time, space, and curricular restrictions as needed (Serrat et al., 2014).

Independent study is another form of SDL. Structured independent learning may improve long term retention of anatomy course content compared to unguided self study (Serrat et al., 2014). Furthermore, independent study and SDL promote life-long learning in students (Serrat et al., 2014), which is important for maintaining professional competency in healthcare practitioners.

**Physical Exercises**
The inclusion of physical exercise and body awareness is a valuable adjunct to anatomical education (McCulloch, Marango, Friedman, & Laitman, 2010). The use of procedural movement and motor memory can be useful for remembering difficult spatial arrangements of vessels and nerves through the use of hand and finger positioning (Oh, Won, Kim, & Jang, 2011).

**Exploring the Exclusion Criteria**
The number of articles removed as irrelevant to the study is not surprising, given the broad nature of the search terms used across the three databases. By retaining a set of broad parameters and searching through a larger number of results by hand, it was expected that more relevant literature could be found and included in the analysis, rather than it remain hidden by the use of more specific search criteria.

The papers that were rejected on the first criterion often used anatomy in a purely clinical context, rather than its instruction in a classroom or educational setting. Along with the second exclusion criterion, this lends support to the idea that the clinical importance of anatomy cannot be dismissed, however the clinical domain of anatomy was not within the scope of this review.
Many of the papers rejected on exclusion criteria two focused on training residents, particularly surgical residents, in anatomy. Again, an analysis of this population lay beyond the scope of this paper. However, it is interesting to note the close tie between anatomy and surgery, and offers more evidence of the importance surgical training places on sound anatomy education. Furthermore, the quantity of papers rejected on this criterion supports the existing notion (e.g., Dusseau et al., 2008; Fitzgerald et al., 2008; Turney, 2007) that medical students are not receiving enough anatomy for safe medical practice, especially in fields where anatomy is essential such as surgical fields.

The third exclusion criterion was the most used in discarding papers from the scoping review, where papers were rejected for discussing anatomy without implementing curricular changes. This suggests that a great deal of literature discussed anatomy curricula and changes that should take place without necessarily taking steps to enact those modifications. This relates to the idea that much of the discussion around anatomy and necessary curricular changes is based on anecdotal evidence (Craig et al., 2010; Vorstenbosch et al., 2011).

A total of 195 papers were rejected on exclusion criterion four, where interrelated concepts such as physiology, embryology, etc., were included in the rejected paper. This paper did not examine those articles as a means to assess purely anatomy education, but it is clear that anatomy is closely related to other key sciences, and may be hard to properly teach in isolation of these other fields. This relationship is bidirectional, anatomy depends on a solid understanding of these subjects in order to be fully appreciated. For example, embryological development explains the confusing arrangement of the mediastinum, physiology explains how muscles contract and move joints about their full range of motion, histology explains the microscopic differences between discreet tissue types within the same organ.
Novel Classification of Tools for Anatomy Education

This paper, and the results of the scoping review, were built upon the work of Estai & Bunt (2016). In the process of this review, 33% of the tools used to educate students in anatomy could not be classified according to the nine categories put forth by the authors. Furthermore, the specificity of integrated curricula in anatomy education for medical students is not relevant to other professions requiring anatomy, and was therefore not widely explored in the literature. Finally, three of their nine categories (cadaveric dissection, prosection, and plastination) focus on the use of cadaveric material, and an additional two categories (integrated curricula and system-based curricula) are not mutually exclusive to the use of cadaveric material. When applied beyond purely a medical curriculum, the various teaching methods for anatomy instruction are not captured or well represented. Even within a medical anatomy curriculum, the combination of cadaveric dissection, prosection, and plastination represented only 20% of the available literature included in this scoping review.

For these reasons, this scoping review puts forward a new framework (Table 4) for outlining the approaches to anatomy instruction that spans multiple disciplines and educational backgrounds. It includes and expands upon the original work of Estai and Bunt (2016) and may be applied to any level or context of anatomy education. Figure 10 shows the distribution of studies across the new categories. However, the re-categorization treats learning tools as individual entities, and does not provide any cl
<table>
<thead>
<tr>
<th>Table 3. Classification and Grouping of Anatomy Learning Tools</th>
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<tbody>
<tr>
<td><strong>Cadaveric - Based Learning</strong></td>
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<tr>
<td>Dissection</td>
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<td>Prosection</td>
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<td>Plastination</td>
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<td>Animal-based dissection</td>
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<td><strong>Computer - Aided Learning</strong></td>
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<td>Applications and programs</td>
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<td>Augmented reality</td>
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<td>Virtual Reality</td>
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<td>Audiovisual materials</td>
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<td>Audience response systems</td>
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<td>3D computer models</td>
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<td>Mobile device usage</td>
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<td>Electronic textbooks</td>
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<td>Online learning and forums</td>
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<tr>
<td><strong>Medical Imaging</strong></td>
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<tr>
<td>CT scans</td>
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<td>MRI scans</td>
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<tr>
<td>X-Rays</td>
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<tr>
<td>Ultrasound</td>
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<tr>
<td>Arthroscopy</td>
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<tr>
<td>3D stereoscopic imaging</td>
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<tr>
<td><strong>3D Models</strong></td>
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<tr>
<td>Plastic models</td>
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<td>3D printing</td>
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<td>Clay Modeling</td>
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<tr>
<td><strong>Student - Led Learning</strong></td>
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<td>Problem - based learning</td>
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<td>Case - based learning</td>
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<td>Team - based learning</td>
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<td>Inquiry - based learning</td>
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<td>Peer teaching and peer tutoring</td>
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<td>Self-directed learning</td>
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<tr>
<td><strong>Independent study</strong></td>
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<td>Blended learning and flipped classrooms</td>
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<td><strong>Living Anatomy</strong></td>
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<td>Surface anatomy and palpation</td>
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<tr>
<td>Body painting</td>
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<td><strong>Traditional</strong></td>
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<tr>
<td>Lecture - based learning</td>
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<tr>
<td>Textbooks</td>
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<tr>
<td><strong>Others</strong></td>
</tr>
<tr>
<td>Motor learning</td>
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<td>Games</td>
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<tr>
<td>Comics</td>
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<td>Art and drawing</td>
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<tr>
<td>Inter - professional learning</td>
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<tr>
<td>Craft models</td>
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<tr>
<td>Youtube, Khan Academy, Kenhub, Coursera</td>
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<tr>
<td>Physical exercise &amp; activities, body awareness</td>
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</table>
Figure 10: Percentage of Categories (Novel Classification)
The redistribution of studies based on Table 4 is provided here. In general, the distribution between the categories is more balanced. The percentages still reveal the higher proportion of medical imaging and computer-aided instruction compared to cadaveric dissection and other traditional methods.
Moving Forward in Anatomy Education: What is Best?

From the results found throughout the literature, one topical question comes forth: should students in their undergraduate anatomy courses be taught anatomy to the same degree as students in professional programs learning anatomy in the context of patient care? This question has two plausible answers. In cases where students begin their professional training with an undergraduate degree, where they took an anatomy course provides a solid foundation from which to build their anatomical knowledge again in later degrees. It is an upstream approach, attempting to solve the problem before it becomes one. However, not all students will have the luxury of being exposed to an anatomy course in an undergraduate setting if they enter medical school from their high school studies, or if they enter a nursing program where the anatomy encountered in those degrees will serve them for the rest of their respective careers. Furthermore, teaching more anatomy to students in undergraduate degree programs necessitates the allocation of more resources in typically larger class sizes, and knowledge retention tends to be low making it a difficult proposition. It seems clear, then, that the needs of undergraduate students is not the same as those of who are going into patient care careers, and as budget and resources continue, it doesn’t seem likely that the undergraduate anatomy class would receive the same level of time, money, and resources as those programs that need it more.

Conversely, some academics ponder if anatomy should be redefined as a postgraduate subject, and taught on a need-to-know basis (Heylings, 2002). The things to learn first in any subject are the fundamentals (Miller, 2000). With this in mind, the question then becomes whether or not anatomy should rearrange itself to become a fundamentals-based course in undergraduate degrees, with field-specific training for students as needed based on their program. This means that only the relevant anatomy is learned to create a foundational understanding of the subject, and resources and time are invested accordingly. This is particularly interesting and relevant to the discussion of anatomy curricula in today’s educational climate, where time and resources are continually restricted. This also has the benefit of
exposing students to the content of an anatomy course and overcomes one of the biggest hurdles in anatomy education, learning the fundamentals. While this is a possible solution, it may not provide a satisfactory outcome. This would take a great deal of coordination between programs, faculties, and institutions to ensure consistency between fundamentals courses, and field specific anatomy courses.

Perhaps it is less important to determine which teaching modality is best, but instead focus on capitalizing the utility of each method (Singh & Kharb, 2013). Certain techniques of anatomy education fit certain healthcare professions better than others (Estai & Bunt, 2016). A prime example of this is cadaveric dissection, which is well suited to training future surgeons more than anyone else. It could be considered an exorbitant expenditure of resources to provide undergraduate students with a dissection experience, especially when that undergraduate degree may not lead to patient care where anatomy knowledge is most important. Still, there is no consensus on what amount of anatomical knowledge is required for healthcare practitioners to safely operate in a clinical setting.

Herein lies the answer to the research question; students in different educational programs are taught anatomy differently, and this is unlikely to change. They are different because of different outcomes of differing degree programs, different amounts of resources and budget sizes, and they vary by teaching methods and strategies. This is not necessarily a problem for student learning either. Cadaveric dissection is still employed in some medical schools, and student outcomes in those institutions are not significantly different from other institutions that do not use cadavers to teach their students. The use of medical imaging makes anatomy more clinically relevant and better prepares practitioners for the reality of clinical work. The increasing dependance on computer-based learning and instruction allows teachers to reach ever-larger classes and has been shown to enhance student learning.
Limitations

The scoping review was limited by the inclusion and exclusion criteria, and therefore it is possible that some studies relevant to the research question were missed when searching databases and other resources. This is compounded by the difficulty in being comprehensive and including all possible literature on the subject at hand. The selection process, by its nature, will miss literature. It was limited to articles published in the last ten years, and only those articles published in English. Clearly, there are relevant articles published before the arbitrary timeframe and relevant scholarship written in other languages that would have contributed to addressing the research question. More databases might have yielded a greater number of papers to help answer the research question.

Furthermore, there was only one reviewer responsible for the process of selecting articles. It is common practice for a scoping review to utilize teams of researchers to complete the review process, providing redundancy and more validity to the results. Because only one author was responsible for this work, the reliability of the findings or replicability of the results may be limited by the bias or fallibility of the author.

Due to limitations in duration and rigour of a scoping review, there is a potential for bias within the findings of the review (Grant & Booth, 2009). A review examining literature over a longer timeframe, or the additional rigour offered by a systematic review would reduce this effect.

Finally, there was no assessment of the quality of the studies used in this scoping review. It is possible, therefore, for studies to be included by virtue of existence, rather than by virtue of quality (Grant & Booth, 2009). It is important to note that assessing the quality of the articles included in the analysis was beyond the scope of this review. While care was taken to ensure that included articles were of sufficient quality, there was no formalized process for assessing the articles included.
Future Directions

In the last quarter century, a broad range of teaching resources have emerged to augment theoretical and practical classes (Vázquez et al., 2007). Ahmed and colleagues (2010) claim that future research in the area of anatomy education should focus on development and validation of new teaching tools. Anatomy educators should feel empowered to continue experimenting with new teaching techniques (Wilson et al., 2019). There should be no reason not to include new and exciting technological advancements (Ma et al., 2016).

This paper did not take the perspective of the student learner or the teacher when assessing the literature. Instead, the paper examined the nature of student education as a process between the teacher and the student. Students must be included in discussions of curricula changes (Aversi-Ferreira et al., 2010). A different understanding of the research question may have arisen if student perceptions of anatomy education was incorporated into the research question or the database search terms. It would be important to consider student opinions and perceptions going forward, regardless of the educational context in which students are taking an anatomy course. Some studies have captured this by examining student comfort with their level of anatomy education (e.g., Fitzgerald et al., 2008; Mitchell & Batty, 2009), but these studies look at the result of an existing anatomy course and often do not gather student perspectives for the purposes of shaping the curricula or selecting appropriate educational interventions or strategies. Furthermore, gathering student opinion is important to help determine if the recent changes in anatomy education are meeting the needs of students, and where more work can be directed to make anatomy courses a meaningful learning experience. In this case, student opinion can serve as a barometer to measure the outcomes of modified anatomy curricula and interventions beyond gathering examination results.

Another key area of research should focus on expanding the learner population. Many papers were rejected from this study because they focused on doctors in their residency training, surgery-specific training, and so forth. These are important
populations of students and professionals where anatomy is important but they were restricted from this scoping review so as to focus in on students themselves.

Another important consideration is the effect of these learning tools on long term retention of anatomy content. Many studies examined only short term impacts of their respective pedagogies. More work is needed to understand how changes in anatomy instruction leads to long term changes in preparing students for clinical work (Wilson et al., 2019). Learning anatomy is analogous to learning to read (Miller, 2000) and while it may be a challenging subject for students to learn, it is a vital component of the training of future healthcare professionals (Ma et al., 2016).

Similarly, further studies could utilize the learning tools and categories identified in Table 4 to gain further insight into the nature of anatomy education. For example, course syllabi could be gathered and analyzed for teaching methods and tools implemented in anatomy curricula. A study could also create and distribute a survey to institutions that teach anatomy to the identified student populations. The results from this type of survey could be compared to the data generated in this scoping review to help validate the results.

Grant & Booth (2009) demonstrate that a weakness of the scoping review lies in its inability to recommend policy or practice. In that regard, this paper serves to summarize the literature pertaining to different educational requirements for the field of anatomy to different student populations. Therefore, a future direction for this research would be to conduct a systematic review to determine if changes to the anatomy curriculum is required. This systematic review could remove the bias created by not assessing the quality of articles before being included in the review, and could provide a better understanding into the process of changing the anatomy curricula to better suit the needs to students.
Conclusion

The purpose of this scoping review was to gain a better understanding of the current state of anatomy education across multiple student disciplines. Anatomy is an interesting domain of education. Its unique nature, including the specific language and terminology, three-dimensional structure, and the direct impact it has on patient care, makes it a difficult subject for experts to teach and students to master. Moreover, it is an important subject because of the close links it shares with safe patient care in clinical and therapeutic settings. It is a subject that is important to multiple disciplines within the domain of healthcare. In this scoping review, students across medical, dental, rehabilitation, nursing, and undergraduate populations were examined to assess the different approaches and techniques to teaching anatomy.

As professional education and expectations change, so do the needs of the students and their own preferences when it comes to their education. This scoping review demonstrated the increasing student interest in CAI, which should not be a surprise given the ubiquitous use of electronic devices in classrooms and daily life. It also demonstrated the increased use and implementation of medical imaging within the classroom setting, which is well-matched to the increased reliance on medical imaging in the clinical setting for diagnosing and treating patients.

Irrespective of the purpose for which students are learning anatomy, course content is complex and can be challenging for learners (Wang et al., 2010). There is no absolute zenith or perfect solution for anatomy education (Smith & Mathias, 2011; Wilhelmsson et al., 2010). However, this fact has not stopped educators from trying to bridge the gap between curiosity and knowledge for their students, and underscores the important impact that teaching strategies can have on anatomy education for all sorts of learners.

New teaching strategies and modalities continue to develop and mature and will therefore continue to receive attention in the literature and positively affect student
learning where implemented. As these new technologies are being integrated in the classroom, the value of more traditional methods should not be dismissed. Cadaveric dissection, which has great historical significance in anatomy training, does not lose merit simply because new pedagogies are being used. Rather, it becomes a more niche form of anatomy training, reserved for those who need it for their training. Furthermore, the use of these technologies can augment the utility of older methods, for example, using medical imaging to complement cadaveric dissection, making lectures more interactive, or using digital textbooks to increase student uptake.

It is encouraging to see an increase in the body of literature surrounding anatomy education, and perhaps the increased awareness and attention can positively address the critical relationship between anatomical training and safe patient care.
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Appendix: Supplemental References


doi:http://dx.doi.org/10.1002/ase.212


Swinnerton, B. J., Morris, N. P., Hotchkiss, S., & Pickering, J. D. (2017). The integration of an anatomy massive open online course (MOOC) into a


# Curriculum Vitae

<table>
<thead>
<tr>
<th>Name</th>
<th>alex wolf</th>
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<tr>
<td>Post Secondary Education and Degrees</td>
<td>B.HSc, Western University</td>
</tr>
<tr>
<td>Awards</td>
<td>Health Studies Award of Recognition (2017)</td>
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| Related Work Experience     | Teaching Assistant: HS 2300A/B (2017-2018)  
                           | Teaching Assistant: HS 3300B (2019)       |