# Anatomy Knowledge Retention in the Macquarie University Chiropractic Program: a cross-sectional study.

*A thesis presented in candidature for the degree of Master of Research*

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**Abstract**

Anatomy education has undergone major reforms in recent years raising concerns for anatomy knowledge retention rates within health-related professions. Chiropractic is one profession that relies heavily on knowledge of musculoskeletal anatomy. This study aimed to test the anatomy knowledge retention rates, at low and high cognitive levels, of the students in the chiropractic program at Macquarie University. It is hypothesised that retention levels will change throughout the program, with an overall increase measured. A 20 MCQ test was developed applying Bloom's Taxonomy categorising the questions into low and high cognitive ability and a survey asking students to rate their units for importance to their musculoskeletal knowledge retention. Students enrolled in the chiropractic program at Macquarie University were asked to participate in both the test and survey. The results showed an increase in anatomy knowledge retention throughout the program. The most significant difference was found between the undergraduate and postgraduate levels in the high order questions. This main finding demonstrates successful vertical integration of anatomy throughout the program leading to enhanced ability to apply anatomy knowledge and increased retention. In addition, students perceived a high-level of integration of anatomy within the program. Testing anatomy knowledge retention at different cognitive levels is a more accurate assessment of retention rates and should be considered for use in future anatomy educational research.

**Candidate Statement**

I certify that the work incorporated in this thesis has not been submitted for a higher degree to any other university or institution.

I certify that the work presented in this investigation is original work except where otherwise acknowledged and referenced in the text of this manuscript.

Ethics committee approval has been obtained from the Macquarie University Human Resources Ethics Committee granted ethics approval on 27 October 2016 (Reference number: 5201600656) (Appendix 11.04).

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## List of Abbreviations

AMEE – Association for Medical Education

ANOVA – One-Way Analysis of Variance

BAT – Blooming Anatomy Tool

BChiroSc – Bachelor Chiropractic Science

CBL – Case-based-learning

CCEA – Chiropractic Council Education Australia

CD – Chiropractic Department

HO – High order

LO – Low order

MChiro2 – Masters Chiropractic two-year Program

MChiro3 – Masters Chiropractic three-year Program

MCQ – Multiple-Choice Question

MeSH – Medical Subject Heading

MQU – Macquarie University

MSKanat – Musculoskeletal anatomy

PBL – Problem-based-learning

SDL – Self-directed-learning

TBL – Team-based-learning

USMLE – United States Medical Licensing Exam

Y1 – Year One

Y2 – Year Two

Y3 – Year Three

Y4 – Year Four

Y5 – Year Five

# 1 INTRODUCTION

The discipline of anatomy is the foundation on which most biomedical and preclinical health science courses are taught[1-7]. Students in biomedical fields are required to develop an in-depth understanding of the structure and function of the human body and the ability to apply this understanding to their future studies in areas such as pathology, differential diagnosis and orthopaedics[8]. Consequently, anatomy is accepted as the foundational area for many health professions[9-13]. Without a strong framework of anatomy knowledge, further study in these professions is difficult because students need to build upon previously acquired knowledge and this involves a complex understanding of the function and relationships of many anatomical structures.

Chiropractic is one of the allied health professions in which anatomy has played an important role in the education of new practitioners[6, 12, 14-16]. The World Federation of Chiropractic defines chiropractic as:

> *A health profession concerned with the diagnosis, treatment and prevention of mechanical disorders of the musculoskeletal system, and the effects of these disorders on the function of the nervous system and general health. There is an emphasis on manual treatments including spinal adjustment and other joint and soft-tissue manipulation.*[17]

As a primary health care provider within Australia, a chiropractor is also responsible for recognising conditions outside of their treatment domain for referral to a more appropriate health care provider. A detailed knowledge of anatomy is a fundamental component of the education of a chiropractor. The Council on Chiropractic Education Australia (**CCEA**) mandates, in their educational standards[18], that anatomy is taught as a component of the basic sciences within an education program. The standards specifically state that the basic science instruction consists of a *"core of information on the fundamental structures, functions and interrelationships of the body systems"* and that this knowledge is *"fundamental to acquiring and applying clinical science"*. It is essential that chiropractors have a detailed understanding of the musculoskeletal anatomy (**MSKanat**) of the body to safely diagnose, treat and prevent disorders and dysfunction of the neuro-musculoskeletal system. While there is heavy emphasis on anatomy education for chiropractors, there is no national curriculum in anatomy for chiropractic programs[6, 19].

Like other medical and health curricula, anatomy in chiropractic is traditionally taught in the early years of the program. This is because the content and language of anatomy provides the foundation for later clinical subjects. However, at this early stage it was often taught isolated from any clinical context that results in an expanded time gap between the acquisition of knowledge and its application. The timing of anatomy delivery and its complex and difficult content led educators in many medical and health professional disciplines to raise major concerns about the retention rates of anatomy knowledge[2-5, 14-16, 20, 21].

Knowledge retention, or knowledge attrition, is an area studied through all levels of education. To shape future teaching methodology, it is important to establish how much initial learning is retrievable after a period of potentially little to no conscious retrieval of that information. This loss of knowledge over time has been reported in biomedical science subjects as being due to lack of application or retrieval of knowledge throughout many programs[10, 22, 23].

Specifically, knowledge retention rates and the factors that have an impact on them have been of great interest in educators in anatomy. For a lengthy period, anatomy teaching had a didactic approach where rote learning and memorisation were the key learning techniques. This made the acquisition of anatomy knowledge largely disconnected from the acquisition of clinical skills. In recent decades, anatomy education has undergone many changes including modalities for content delivery, reduced time (for both laboratory and lecture), and its place within curricula. In most programs, the overall hours dedicated to formal anatomy education have decreased and there has been a shift to modernise the delivery of content to increase active- and self-directed-learning (**SDL**)[2, 4, 5, 24, 25]. Many programs have now integrated anatomy learning and increased the application of anatomy throughout their program[26-29]. This design of revisiting anatomy throughout a curriculum is known by educators as vertical integration, or spiral integration, and is directed toward increasing students' depth of knowledge.

The premise of these changes is that students learn the same amount of material in a shorter time but revisit it in other subjects throughout the program. When the anatomy is revisited it is clinically applied to reinforce and enhance students' knowledge[9, 28, 30, 31]. The importance of clinical relevance to retaining anatomy knowledge has become so well established that many educators are adapting new methods of teaching anatomy to capitalise on this impact. The new approach to learning in a clinical context is perhaps best exemplified in the Problem-Based Learning (**PBL**) model, which is being adapted in the core teaching of anatomy, in the form of

Case-Based-Learning (**CBL**), to bring earlier clinical relevance to the material[27, 28, 32-36]. The expectation is that by having an earlier clinical application of knowledge, retention rates, depth of understanding and the students' ability to apply their anatomy knowledge will improve. The intent is that vertical integration of anatomy knowledge with its application will give students a much higher level of understanding and interpretation in the later subjects of the curriculum as more time is spent interpreting, applying, integrating their knowledge and building clinical diagnostic skills rather than having to relearn foundational knowledge[31, 33, 37]. In addition, they will develop high order cognitive abilities to apply information earlier[27, 35, 38].

The evolution in anatomy education has been shaped by a variety of factors including new technologies, resources, research into modernised teaching techniques and recognition of different learning styles. These changes are aimed at improving the efficiency and cost effectiveness of teaching while improving the experience and outcomes for the student [4, 11, 39, 40]. By making the course more efficient there is room to include development of greater professional skills and competencies that have not been traditionally taught to improve the quality of the graduate and better equip them for their entry into clinical practice and the workforce[4]. The efficacy of these changes in achieving what was intended is the major focus of current anatomy educational research, and a key metric is the anatomy knowledge retention rate.

A wide range of educational research in anatomy is focused on anatomy knowledge retention rates in medical programs, because these have the largest and longest standing programs in anatomy education. However in recent decades, universities have expanded their offerings of health science courses thus increasing the demand for anatomy education[24]. These anatomy education programs, while sharing similar core basic science subjects, vary greatly in the latter years of courses depending on the specialty. In addition, the level of detail expected to be retained for the latter years of study is different and adaptation of medically orientated anatomy programs may not give the necessary curricula structure, or emphasis on the correct content, to achieve the required outcomes for future study in that field.

With the growth in allied health education in larger institutions there has been an increase in anatomy educational research. Comparative studies have been conducted testing different groups of students in different programs and across disciplines with the same anatomy questions[8, 12, 13, 15]. The results of these studies showed varied results and reflected the different level of anatomy and different emphasis of regional anatomy required in different programs. What these studies showed was that retention rates between different anatomical body regions will differ (e.g., head and neck anatomy versus limbs) and that these patterns of retention rates may differ within a different program of study that has a different emphasis (e.g. medicine versus physiotherapy). Even within the same field, tests conducted at different institutions which focused on the same anatomy have yielded different retentions rates[10, 12-16]. This makes it very difficult to transfer results of many studies across different programs of study.

Although the outcomes of these studies have varied, their shared goal has been to assess how much knowledge students have at varying levels of study or between different health-related programs. They have also sought to account for differences between these groups and to assess ways to improve learning and retention of knowledge.

Dynamic and rapid changes in curricula of many biomedical courses have meant that anatomy knowledge retention rates are now a common measure of whether these changes have altered the students learning[7, 27, 30, 34, 35]. However, the problem that arises with comparing studies that are using retention rates as a measure, is the lack of standardised methodology for testing anatomy knowledge.

While there are many factors that will influence knowledge retention rates[1, 20, 36, 41, 42], testing anatomy retention rates purely on content of material may not give an accurate reflection of other skills acquired throughout the student's learning. The question that has been raised in the literature is whether testing purely acquired knowledge content, when testing retention rates, is a true reflection of all the learning that the student has achieved[35]. The expansion of testing would then include a measure of the student's higher cognitive abilities that may also have been acquired. Considering most changes to teaching methodology were designed to encourage analytical thinking, it would be pertinent to factor in measurement of this change to cognitive ability.

A universally acknowledged categorisation of cognitive levels is defined in Bloom's Taxonomy [43]. These definitions are used throughout educational settings for curricula mapping and to create a tiered learning structure. It is commonly utilised in testing within the education environment to standardise achievement levels of learning and therefore guide marking rubrics. The difficulty in anatomy education, which has historically been defined by pure content, is how to test anatomy above the lower cognitive levels, especially in a multiple-choice format.

Thompson et al.[44] developed the Blooming Anatomy Tool (**BAT**) (Appendix 11.01) to define criteria that can be applied to testing anatomy questions in a multiple-choice format. This criterion specifies the components that an anatomy multiple-choice question requires to fit into four different levels of Bloom's Taxonomy and more accurately into higher and lower cognitive ability.

The multitude of factors that influence anatomy retention rates makes the measurement and analysis of them a highly complex process[1, 4, 41]. This complexity of retention rates is further heightened when considering retention rates may vary at different cognitive levels.

Due to the diversity of anatomy curricula and teaching deliveries it is pertinent that anatomy retention rates are investigated in different settings, in their totality and related to different body regions and systems.

This thesis focuses specifically on retention of musculoskeletal anatomy (**MSKanat**) across a chiropractic program as outlined with the following research question.

# 2 THE RESEARCH QUESTION

The primary question of this study was ***'What are the retention rates of MSKanat knowledge of chiropractic students studying the chiropractic program at Macquarie University?'***

From this primary question, a series of subsidiary questions arise that are required to formulate a complete answer.

***2.1 Do retention rates of MSKanat knowledge change throughout the program?***

***2.2 If a change in anatomy knowledge retention rates is present, does it follow a normal attrition of knowledge curve?***

***2.3 How do anatomy knowledge retention rates differ at two different (low and high) cognitive levels, according to Bloom's Taxonomy across the program?***

***2.4 Does vertical integration of anatomy learning throughout the program facilitate a change in anatomy knowledge retention rates at different cognitive levels according to Bloom's Taxonomy?***

***2.5 Which parts of the program do the students perceive has been important for their MSKanat knowledge?***

## 3 HYPOTHESES

Regarding the primary question, the hypothesis is that retention rates of MSKanat knowledge of chiropractic students in the chiropractic program at Macquarie university will likely increase throughout the program.

Regarding the subsidiary questions:

3.1 There will be changes in MSKanat knowledge retention rates throughout the different levels of the chiropractic program at Macquarie University.

3.2 Anatomy knowledge retention rates may suffer attrition in the early part of the program but there will be an increase in knowledge retention in the later clinical stages of the program.

3.3 Students in first and second year will score higher, relative to the later year levels, on the questions designed to be low order questions, and lower on questions designed to be high order questions. Students in the later years of the chiropractic program will score higher, relative to the earlier year levels, in the high order questions than the students in the early years of the program, but may score lower in the low order questions.

3.4 There will be higher levels of anatomy knowledge retention in the later clinical years of the program, reflected by higher scores particularly in the higher order questions which will correlate with the vertical integration and clinical application of anatomy learning in the program.

3.5 Students' perception will change throughout the program of where MSKanat has been integrated the program.

## 4 AIMS AND OBJECTIVES

The aims and objectives of this study were to:

4.1 Establish student knowledge of anatomy at all year levels of study in the chiropractic program at Macquarie University.

4.2 Outline the pattern of anatomy knowledge retention rates throughout the chiropractic program, at two different (low and high order) cognitive levels according to Bloom's Taxonomy.

4.3 Explore the association between anatomy knowledge retention rates at two different cognitive levels and volume of vertical and clinical application of anatomy knowledge throughout the chiropractic program at Macquarie University.

4.4 Explore student perception of anatomy knowledge retention and their program of study.

# 5 LITERATURE REVIEW

Knowledge attrition, the reverse of knowledge retention, is the loss of retrievable knowledge after the initial formal learning. While there are many factors that will affect knowledge retention, one of the key factors that leads to attrition of knowledge is if information is not actively retrieved or used after its initial acquisition. Studies have sought to measure this loss with variable results. While the exact figures are variable(22, 23, 34, 45) it has been shown that attrition over time follows a similar pattern. This pattern or "attrition of knowledge curve" demonstrates that there is a steep decline in knowledge retention after the initial learning if that knowledge is not used. The rate will then slow but will continue if the information is not revisited (22).

Within the biomedical field an estimate of attrition rates of basic science knowledge is 50% loss of knowledge in the first year, and a further 25% over the next two years with no recall of that information(22). However, retention rates within basic sciences vary between subjects with biochemistry and pharmacology suffering the worst losses and by comparison, anatomy a more modest loss. This difference is often accounted for by the perception students have of the relevance of the subject impacting their desire to learn it and therefore their retention levels of that material(23). Anatomy is often perceived by students enrolled in health related programs as being more important than chemistry, contributing to better retention rates(46).

The aim of this review was to investigate the literature on knowledge retention rates in anatomy education, focusing on the factors impacting on knowledge retention rates in anatomy such as curricula, teaching methods, student engagement and use of resources. The review focused on which sub-disciplines of anatomy knowledge retention rates have been studied, how they have been assessed, what the results have revealed and what factors were identified as affecting retention rates. Special emphasis of this literature review was to examine the different fields in which anatomy retention rates have been studied, the differences between testing methods and how transferrable they are between the different fields of anatomy when it is studied as part of a core curriculum.

The final objective of the review was to summarise current knowledge to allow curricula designers to achieve maximum anatomy knowledge retention rates in their cohorts allowing for a strong foundation for their future clinical studies.

## 5.1 Methodology of Literature Review

The journal article search process (Figure 5.1.01) was carried out using Medical Subject Heading (**MeSH**) terms which were entered into multiple data bases between July and September 2016 (Table 5.1.02). The initial database used was Thomson Reuters Web of Science (formerly Web of Knowledge), followed by Scopus and PubMed, for an extensive search and reading of articles. The initial searches first used the MeSH terms "anatomy" and "knowledge" and "retention" with their related terms (Table 5.1.01.).

| Table 5.1.01 Literature Search Terminology | |
|---|---|
| *MeSH Terms* | *Related Search Terms* |
| Anatomy | Anatom* |
| Knowledge | Knowledge |
| Retention | Retention OR Retain |

The MeSH and all the related terms (Table 5.1.01) were then combined using "AND" (Table 5.1.02) for a detailed search. Duplicates were identified and removed from the list of publications. Exclusion criteria (Table 5.1.03) were applied to the detailed search to remove papers that were not relevant or were not written in the English language. No restriction was placed on the date of publication as most changes in anatomy education started around 1990 and most publications that were appropriate to this study started in the subsequent decade. Articles were included if they related to the teaching of anatomy, testing anatomy knowledge, knowledge retention rates in basic or biomedical sciences, or the factors affecting the successful teaching and learning of anatomy and therefore knowledge retention.

| Table 5.1.02 Results of Literature Search | | | | | |
|---|---|---|---|---|---|
| ***MeSH Term*** | *Search Terms* | *Web of Science (No)* | *Pub Med (No)* | *Scopus (No)* | *Total (No) Terms combined with "AND"* |
| **Anatomy** | Anatomy or Anatom* | 260,820 | 4,682,863 | 509,105 | 247 |
| **Knowledge** | Knowledge | 973,818 | 571,879 | 1,511,611 | 439 |
| **Retention** | Retention or Retain | 454,024 | 188,189 | 418,352 | 148 |

| Table 5.1.03 Literature Database Search Criteria | |
|---|---|
| ***Inclusion Criteria*** | *Exclusion Criteria* |
| • **Test anatomy knowledge**<br>• **Test anatomy knowledge retention**<br>• **Review of anatomy in curricula and effect on anatomy knowledge**<br>• **Test impact of teaching methodologies/learning strategies on knowledge retention levels** | • Medical/surgical technique training<br>• Animal anatomy/ physiology/ Christmas trees<br>• Medical cases<br>• Medical specialty programs<br>• Teaching methodology not linked to anatomy knowledge<br>• Anatomy/anthropology studies<br>• Reviews of anatomy training into specialties<br>• Not written in English language |

The final selection (Figure 5.1.02) process involved screening the articles once the exclusions had been applied. Titles of papers and abstracts, and chapter titles from books from the search were screened to identify if they were relevant for the review. Papers were excluded if the topic was extremely narrow and specific to surgical anatomy, surgical procedures or pathological conditions or were commentary articles. Full text records were removed if they did not fit the criteria of testing anatomy knowledge, learning or retention of anatomy knowledge or assessing the factors affecting retention of knowledge in anatomy.

Articles were included if they were original research papers both qualitative or quantitative as well as reviews on the topic. Articles were screened and reviewed for quality in their design. The assessment of the quality of the studies was based on their sample size and the validation of their tests.

**Figure 5.1.01 Literature Search Methodology**

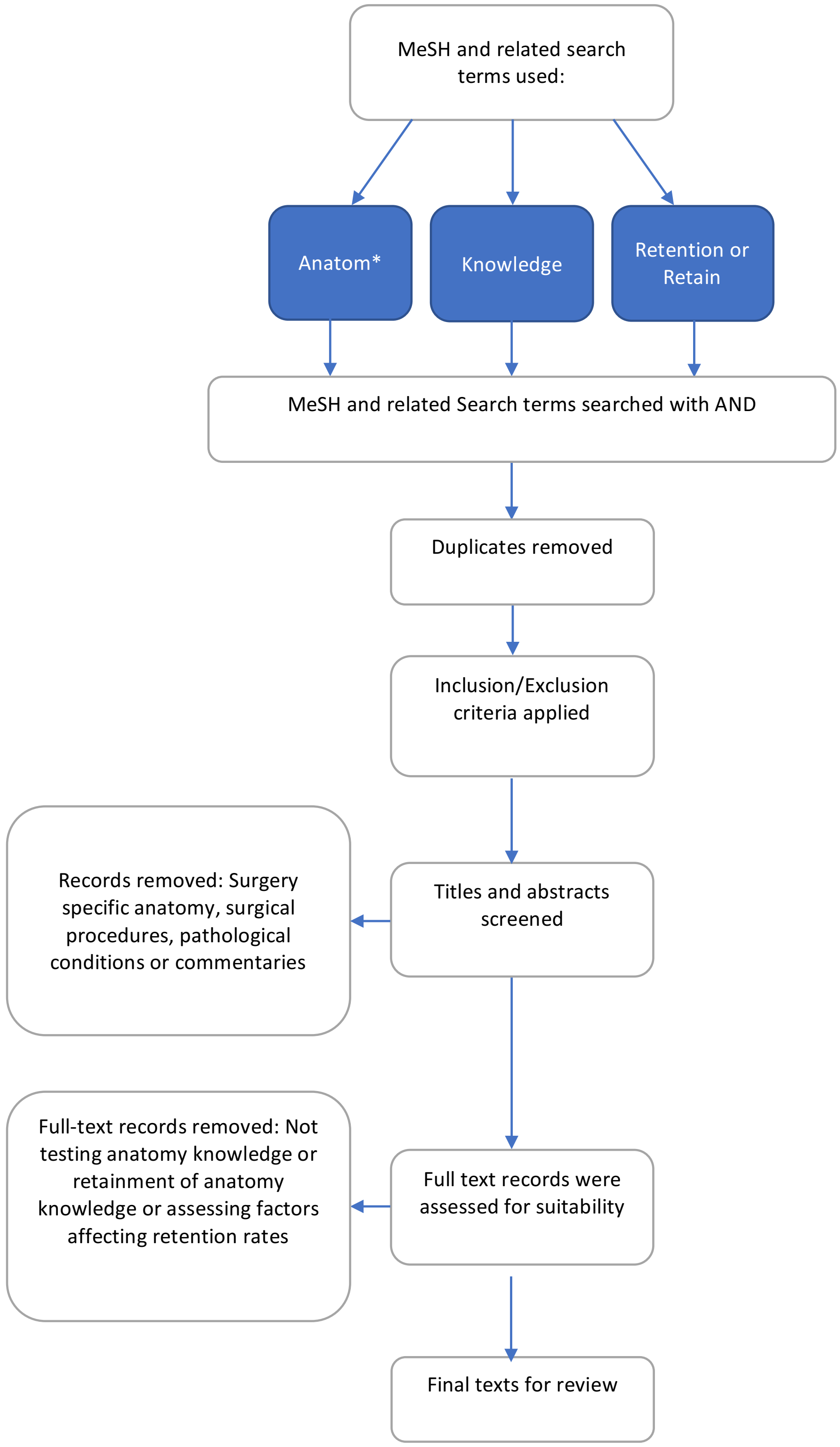
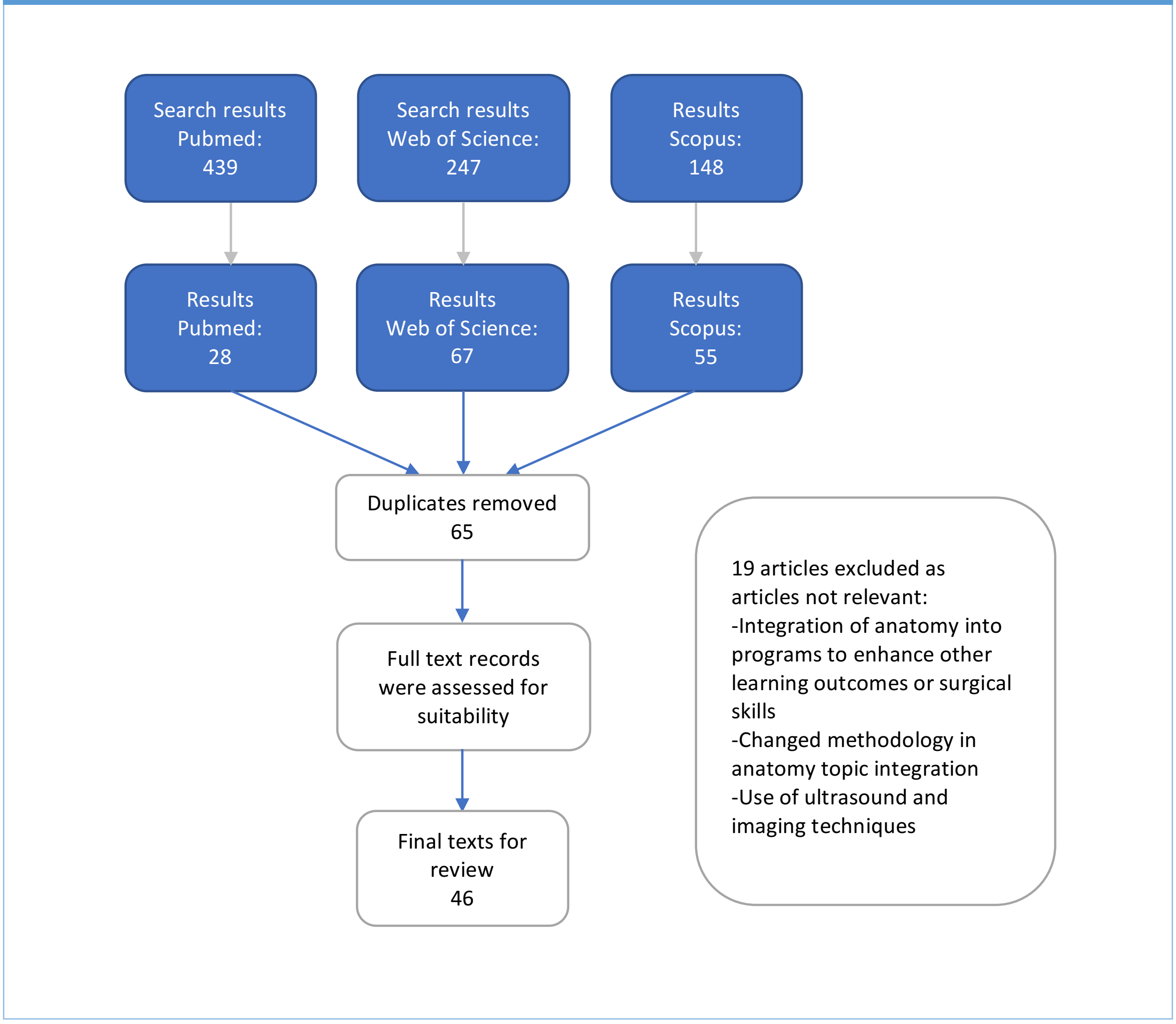


Figure 5.1.02 Selection Process for Literature Review




## 5.2 Results of Literature Review

A total of 46 papers were identified and selected (Figure 5.1.02) as appropriate to the topic of anatomy knowledge retention in anatomy education. These papers were categorised into four main themes with some overlap between them, relevant to the main topic. The categories were:

- the effect of curricula structure on anatomy knowledge retention rates;
- testing and feedback as a method to increase anatomy knowledge retention;
- old resources vs new technology and the effect on anatomy knowledge retention; and
- learning strategies in anatomy to engage the student and the impact on retention.

The selected studies contained a combination of qualitative and quantitative studies. A limitation of this study is that research conducted on students in anatomy education always carries a potential risk of bias. This is usually due to some or all the authors of the research being involved with the teaching of the students being tested. Studies often assess retention rates using the assessments conducted in the teaching of the unit and are therefore aligned with the learning objectives of the unit. As these learning objectives are rarely provided with the study, any findings are potentially subjective. Test bias could be reduced if the objective aims of the teachings are stated, or the expected learning requirements are indicated. In addition, few randomised control trials exist mainly due to the ethical considerations of an intervention in an educational setting.

## 5.3 Discussion of Literature Review

Anatomy knowledge retention rates are complex to study as they are impacted by many factors. Some of the major factors include: (1) how anatomy is incorporated into a curriculum, (2) how often anatomy is tested, (3) what resources are used in the instruction of anatomy and (4) the learning preferences of individual students.

### 5.3.1 The effect of curricula structure on anatomy knowledge retention rates

The introduction of teaching innovations and integration of anatomy within medical curricula has not been uniform or simultaneous across different institutions. Bergman et al.[(32)] have outlined the complexity of this topic as it goes beyond the methods used to teach anatomy, but to what level of detail, its clinical relevance and where within a curricula it is best taught. This has led to several studies testing anatomy knowledge to assess the impact of these changes in anatomy education on anatomy knowledge retention rates. That is, are the teaching innovations and integration of anatomy into curricula having positive results on students' anatomy knowledge and their ability to apply it clinically?

The widely-asked question in the literature regards the anatomy knowledge of students and what the acceptable levels should be[(32)]. Studies have sought to quantify the anatomy knowledge of the students in their programs but with no "gold standard" method of testing, results have varied greatly. The carpal bone test, which requires students to correctly name the eight carpal bones, has been used several times in different studies[(12-14, 16)], and yielded varying results at different institutions and in different fields of study where it has been tested.

It has been considered by these authors, although being a very limited test, as a preliminary indicator of MSKanat knowledge retention. As a standardised and repeatable test it has allowed intra and inter disciplinary comparisons within this specific region of anatomy in various studies.

The use of this test has shown a higher retention of knowledge in disciplines that have a greater musculoskeletal focus such as chiropractic and physiotherapy, and a lower retention in disciplines with less emphasis on MSKanat like medicine [10, 12]. Studies using the carpal bone test conducted within the same field, as has been done within chiropractic, have yielded different results between the different programs of study[14, 16]. This is possibly a reflection of the different levels of vertical integration of anatomy and clinical application within these programs resulting in different levels of anatomy knowledge retention of the students. The differences in results elicited by testing a population group that has a different focus in anatomy education, or has a different curricula design of anatomy integration demonstrates two variables that make drawing conclusions difficult.

Brunk et al.[8] and Prince et al.[21] both used a modified Angoff procedure. This procedure utilises a panel of experts to review every question of an exam paper to determine what percentage of people meeting minimum standards could answer the question correctly. From this assessment a pass mark for the exam is developed. Both papers used the procedure to attempt to answer the common question of whether students know enough clinical anatomy. Both studies returned the same result. The majority of the students tested failed to meet the benchmark score set by the panel of experts to be deemed to have an acceptable level of anatomical knowledge. However, neither study addressed the issue as to whether this was because of a lack of acquisition or retention of the anatomy knowledge.

The work by Custers et al.[22] in measuring knowledge attrition rates of the basic sciences established that 50% of basic science knowledge is often lost after two years if that information was not being used or revisited in that time. The premise of vertical integration of anatomy in modern curricula is to revisit anatomy knowledge in an applied fashion as it becomes clinically relevant to enhance rebound learning and to deepen students' understanding and translation of their knowledge into clinical practice[31, 37]. The work of Custers et al. provides good evidence for the importance of vertical integration of anatomy knowledge and provides a base line for comparison for other authors to assess expected knowledge retention rates where there has been no educational revisiting of material.

Vertical integration and CBL/PBL have become major foci within the educational system. Studies have strongly identified that a student's perception of clinical relevance of the material and learning it in context are important factors in (1) motivating them to learn the material, (2) achieve better long-term retention, and (3) transfer of that knowledge into clinical practice[9, 27, 28, 47]. Doomernik et al.'s[48] recent study on anatomy knowledge attrition rates in a program of study that was strongly designed around vertical integration of anatomy, demonstrated a much lower attrition of anatomy knowledge compared to those demonstrated by Custers et al.[22]. The concept of initial exposure to material followed by repetition and reinforcement of material as it becomes clinically relevant throughout the educational program has been shown to lead to better retention in follow up post learning examinations[7, 28, 30, 37, 49]. If the information has not been adequately retained with the first exposure to the material, subsequent exposure leads not only to an increase in amount of knowledge acquired but also better retention of that knowledge. This is known as the rebound learning effect whereby retention increases more with every exposure[31].

Acknowledgment of clinical application and repetition of material throughout programs is widely agreed to enhance knowledge retention levels. However, the success of the execution of CBL and particularly the extreme form of that integration (i.e., flipped classroom), is largely debated. The flipped classroom is a new teaching format whereby the first exposure to new material is done through resources outside of the classroom. Here, face-to-face contact hours are dedicated to discussion and problem-based application of relevant material. Studies looking to measure the success of this format, while able to quantify the knowledge retention rates of their students, faced the difficulty in being able to measure these against anything[50, 51]. Bergman et al.[36] found that PBL alone was not enough to ensure retention, while Prince et al.[34] reported that PBL is no worse than traditional methods of teaching. Looking at whole curricular structure, integrated CBL has been shown to be both successful[38, 52] and unsuccessful[2].

It could be hypothesised that these differences link more to, not the style itself, but the execution and curricula framework within which they exist. In addition, there is a tendency to leap towards these new methods of teaching and forget the essential elements that underpin education. With the theme to these changes being that students are encouraged to learn in a way where understanding replaces rote learning[9]. Magid et al.[31] suggest that traditional memorisation may be an undervalued element of learning in modern teaching methods. A degree of rote learning may be required when students are first exposed to material so that they can then apply it, and that this rapid shift towards new teaching methods may be ignoring the obvious tried and tested.

One of the major issues that is not well addressed in the literature (but is evident as research into the anatomy knowledge retention rates in modern curricula and anatomy education increases) is how poorly results from one study transfer to another. What standard of measurement is appropriate to be used and how can this be compared? Cuddy et al.[51] attempted to use United States Medical Licensing Exam (**USMLE**) performance as a bench mark for assessment of changes to anatomy instruction with little to no results. The small differences that were noted were that curricular approach and laboratory exposure may be an identifiable component that affects retention of anatomy knowledge, while teaching time may not have a major influence. The lack of differences between student's examination results from different program designs could reflect that the different teaching formats and integration of anatomy do not influence anatomy knowledge retention. As Morton et al.[35] questioned, difference could be secondary to a deficiency in the structure of assessment that is being used. If one of the instigating factors for change to anatomy instruction was to graduate students with enhanced clinical skills with an increased ability to apply their knowledge in a clinical setting, then measuring retention of knowledge in new curricula should not only focus on straight anatomical facts, but also seek to measure students' ability to apply it[40].

Bloom's Taxonomy has been a well-established educational standard method of assessment of progression of educational ability[43]. Morton et al.'s[35] work on assessing the impact of instigating a flipped classroom raised the question as to whether the true difference in student outcomes from teaching changes may not be in the amount of anatomy that a student learns, but in their ability to apply it. With it being established that programs of study in different disciplines are moving towards teaching methods and course structure to increase students' knowledge retention and ability to use the knowledge clinically, then studies should assess this by testing not only fact content but development of understanding using Bloom's Taxonomy. This would allow studies to not only assess knowledge retention, but track students' greater depth of understanding. In addition, given the complexity and limitations of research in retention rates due to the variety of methodology in quantifying retention rates, compounded by the diversity of content and curricula design and structure application of Bloom's Taxonomy may potentially give greater quantifiable and transferable results to research in this field.

### 5.3.2 Testing and feedback as a method to increase anatomy knowledge retention

With changing curricula design and integration of anatomy within these curricula, there has been a growth in research assessing critical factors that should be integrated into course design to maximise retention of anatomy knowledge.

Recent work has shown that regular testing is a powerful tool for learning and retaining information on anatomy[53-55]. The act of having to repeatedly and actively free-call[53] information, in a formative or summative assessment, will lead to better retention. The assumption of the process of actively having to recall information leading to better retention of that knowledge also fits with Guadagnoli et al.'s[56] work on challenge point framework in medical education. While this model is a theoretical basis to conceptualise the effects of different practice condition for motor learning, the basic premise of this model can also be applied to non-motor learning. For testing to increase retention there needs to be adequate and appropriate cognitive challenge for optimal learning to occur. That is, a test that has marks that contribute to a final grade will have a greater impact on learning than a practice quiz. However, the assessment weighting needs to be appropriate otherwise the stress associated with the ramifications of that mark could have a negative impact on the test effect. Practice quizzes have also been shown to be useful, and in addition, a predictor of summative assessments. However, timing and use of practice quizzes need to be taken into consideration as influencing factors if they are to be considered a true reflection of student performance[57].

An important component to testing to enhance retention is also corrective feedback[58]. Not only is it important for the learning process for correction of inaccuracies, but the feedback also needs to be timed in conjunction with the complexity of the task. That is on simpler tasks students should receive a more immediate response but there needs to be greater time before feedback on more difficult tasks to allow for self-reflection. Audience response systems have been integrated into lectures in anatomy, and the combination of testing with immediate feedback in a lecture environment have shown to have significant positive correlations to improved examination results and knowledge retention[59].

In the current era of education, the emphasis in many curricula is on clinical application of knowledge and learning through case based approaches. A recent randomised cross-over trial by Raupach et al.[55] has shown that repeated testing was more effective than repeated CBL at developing clinical reasoning. This effect was also evident in the retention rates.

While these studies have faced the same challenges of many educational studies of comparability, they have highlighted the need to not discount some traditional educational approaches as they could be the same, if not more effective, at achieving the same goals of modern curricula.

### 5.3.3 Old resources vs new technology and the effect on anatomy knowledge retention

One of the challenges in anatomy education is that it requires students to develop a spatial awareness of the body to be able to identify and inter-relate structures. To teach this three-dimensional (3D) spatial awareness dissections, embalmed prosections and physical models have been traditionally used. Technology and 3D visualisation technologies are becoming increasing available and enticing, due to their advancements in realism[60, 61], as a potential replacement to cadavers and the challenges that teaching with real tissues presents.

Technology can either be used as an additional resource to conventional teaching or as a replacement. When tested for short and long term retention of knowledge, computer-based programs using 3D models that were instigated to replace traditional learning methods were found to not be statistically different or less effective[61-65]. As an adjunct to traditional learning, online 2D resources have been shown to enhance students' performance on cadaveric exams. By comparison, studies on whole body dissection have shown it to be an effective method of teaching anatomy and retention of knowledge[66, 67]. Burgess[68] also showed the combination of new teaching methods and team-based-learning (**TBL**) with traditional methods and dissection, to be effective for learning. However, more research is needed on what components of that combination led to its effectiveness.

Computer-based technology is deemed to have many advantages and has been shown to be more beneficial for students in developing 3D spatial awareness compared to 2D images in text books[69]. However, 3D physical models which have been used in anatomy education for a long time have been shown to yield better results than all other educational methods for developing overall knowledge, developing spatial knowledge and greater knowledge retention rates[60, 61].

Advancements in technology are not only restricted to 3D-visualisation software. Virtual microscopes, tablets, laptops and better printers have often meant that paper and pencil drawings are less likely to be performed by students. When applied specifically to the study of histology, actual drawing of images has been shown not only to increase acquisition of knowledge but significantly improve retention[70]. Which component of drawing images that leads to better retention remains to be determined. That is, whether this benefit is due to the increase of time on task, the influence of kinaesthetic learning, or simply the development of active rather than passive learning.

With the increasing excitement regarding the advancements in 3D visualisation and other technologies, the risk is more traditional methods may be disregarded without reason. However, the demand for their inclusion is increasing with the 'digital generation' being more likely to acquire information through digital resources as that generally forms the basis of their educational career to date(71). Newer technologies have great potential as additional resources, but need to be assessed for effectiveness if to be used as a replacement for more traditional modalities.

### 5.3.4 Learning strategies in anatomy to engage the student and the impact on retention

Modern educational research is delving into the components that assist students' learning. The categorisation of the different learning styles of individuals(40) has enabled educators to offer resources to cater for as many styles of learning as possible to benefit their students. The responsibility to engage students with the material to achieve results has been placed back on to the educators.

Body painting is one activity that has been explored to engage students to learn as well as to appeal to visual and kinaesthetic learners to create better learning and retention. While it is usually well received by students(72-74), it has not been shown to lead to any significant difference in knowledge retention(74). The benefits of this activity may lie outside the scope of retention in the traditional cause and effect sense, but may contribute better to the bigger picture. If the student is actively engaged and enthused about anatomy, is more relaxed in the formal educational setting and has built better working relationships with their peers they may proceed by applying themselves better to their studies.

Similarly, anatomy board games have been used as an intervention to engage students. In addition to having a positive influence on their perception of learning anatomy and development of TBL it showed improvement on their knowledge acquisition(75). A component of this success could be linked to the creation of academic competition, which when established without creating additional stress, can improve academic results through stimulation and engagement(71). The other benefit of these activities and others like them (clay modelling, construction of skeletal muscles) is that it encourages active learning which is more effective at increasing retention compared to passive reception of content[76, 77].

### 5.4 Conclusions from the Literature Review

Anatomy knowledge retention rates vary between disciplines, region of anatomy and programs of study. Changes in teaching methods and integration of anatomy into programs are having mixed outcomes on retention. The majority show an increase in anatomy knowledge retention in programs designed with vertical integration of anatomy teaching. Additional studies have shown increase of retention with learning strategies and resources introduced to engage the students into active learning. Repeated testing, requiring the student to actively recall material, has shown to have a critical role in developing and improving retention. While these studies show promising increases to students' anatomy knowledge retention, further research is needed to examine if students' depth of understanding is developing as well. And if so, can this be quantified and become a standardised element of testing to make results from studies more generalisable.

# 6 THE RESEARCH

## 6.1 Methodology

This is a cross-sectional study. This study design was chosen over a longitudinal design for two reasons. First, a cross-sectional design enables a clear view of what is currently occurring across different groups (years of study). Second, the study was limited by the nine-month time frame of the second year of the Masters of Research program.

## 6.2 Setting

This study was conducted at Macquarie University (**MQU**) within the Chiropractic Department (**CD**). The CD runs three different programs of study. The first is a three-year Bachelor of Chiropractic Science (**BChiroSc**), the second is a two-year Masters of Chiropractic (**MChiro2**) and the third is a three-year Masters of Chiropractic (**MChiro3**). The last is a standalone alternate pathway for students. Application to the MChiro3 is available to students who have completed an undergraduate health/science degree at another university. Applicants are required to have the prerequisite learning (introductory and MSKanat) equivalent to some of the non-chiropractic specific subjects in the BChiroSc. Students graduating from MQU need to have completed the BChiroSc and the MChiro2 to be considered for registration in Australia which allows them to practice as a qualified chiropractor. An alternative to qualify to apply for registration is the student has an undergraduate health/science bachelor degree with the required prerequisite learning and has completed the MChiro3.

The design of the chiropractic curriculum at MQU includes the majority of units (modules) designed and taught by the CD and several units that are designed and taught by other departments (Table 6.2.01 and 6.2.02). The units designed and taught by the CD are a mix of units only available to students enrolled in the chiropractic program and units that are designed for the chiropractic curriculum but are open to enrolment from other programs. All anatomy units within the chiropractic program (Hlth 108 – Introductory anatomy, Hlth109 – Limbs and back anatomy, Hlth213 – Head, neck and trunk anatomy and Hlth214 – Neuroanatomy) belong to this last category.

The chiropractic program at MQU has remained largely unchanged since its redesign in 2010. The design of the program aimed to increase the focus of the bachelor to larger more evidence based, clinically orientated subjects and reduce unnecessary repetition and focus on basic science content such as physics and chemistry. This included the removal of some basic science subjects and the restructure of other clinically based subjects. The redesign also involved major changes to the structure and position of anatomy in the program. These changes involved the program going from six units (Introductory anatomy, histology, limbs anatomy, back and trunk anatomy, head and neck anatomy and neuroanatomy) taught over the entire three years of the BChiroSc, to four units taught in the first two years of the BChiroSc (Hlth 108, 109, 213 and 214). The redesign of the anatomy curriculum did not mean a drastic loss of teaching time with the overall hours going from 325 hours to 312 hours. The restructuring included modernisation which supported the accelerated learning including the integration of clinical CBL to apply a strong clinical application to the initial learning. In addition to the changes to the anatomy units the new structure of the program meant that anatomy was integrated into every year level. This meant anatomy was revised within each clinical subject throughout the program as it became relevant to the clinical skills. The new program therefore had earlier clinical relevance to the anatomy teaching and substantial vertical integration.

| Table 6.2.01 BChiroSc Curriculum 2016<br>* Indicates units not developed and taught by the CD. | |
|---|---|
| ***Course Code*** | *Description in 2016* |
| **BIOL 108 & 115 *** | Human Biology & Genes to Organisms *(Introductory and genetic biology)* |
| **CBMS 103 *** | Organic & Biological Chemistry |
| **HLTH 108 & HLTH 109** | Introduction to Anatomy & Anatomy of Limbs & Back |
| **CHIR 113 & 114** | Chiropractic Sciences 1 & 2 *(Manual therapies and evidence-based clinical practice)* |
| **BIOL 257 & 258 *** | Systems Physiology & Neurophysiology |
| **CBMS 223 *** | Biochemistry |
| **HLTH 200 OR ANTH 202 *** | Contemporary Health Issues or Illness & Healing *(Introduction to multi-disciplinary field of health studies or Medical anthropology)* |
| **HLTH 213 & HLTH 214** | Anatomy of Head, Neck & Trunk & Neuroanatomy |
| **HLTH 215** | Principles in health & Disease 1 |
| **CHIR 213 & CHIR 214** | Chiropractic Science 3 & 4 *(Manual therapies and evidence-based clinical practice)* |
| **HLTH 333** | Clinical Diagnosis *(Clinical problem solving and differential diagnosis)* |
| **HLTH 306** | Research Methods for Health Science |
| **HLTH 316 & HLTH 317** | Principles in Health & Disease 1 & 2 *(Pathophysiology)* |
| **HLTH 304** | Radiographic Physics & Protection |
| **CHIR 315 & 316** | Chiropractic Science 5 & 6 *(Manual therapies and evidence-based clinical practice)* |

| Table 6.2.02 MChiro2 Curriculum 2016 | |
|---|---|
| ***Course Code*** | *Description in 2016* |
| **CHIR 873 & 874** | Neuro-musculoskeletal Diagnosis 1 & 2 *(Clinical neurology and orthopaedic examination and diagnosis)* |
| **CHIR 891 & 892** | Clinical Chiropractic 1 & 2 *(Manual therapies, evidence-based clinical practice and research skills)* |
| **CHIR 896 & 897** | Clinical Internship 1 & 2 |
| **CHIR 903 & 904** | Clinical Chiropractic 1 & 2 *(Manual therapies, evidence-based clinical practice and research skills)* |
| **CHIR 916 & 917** | Diagnostic Imaging 1 & 2 *(Radiographic positioning and interpretation)* |
| **CHIR 918** | Physical & Functional Assessment *(Clinical systems examination and functional assessment and rehabilitation)* |
| **CHIR 919** | Clinical Patient Management *(Clinical reasoning skills)* |
| **CHIR 921 & 922** | Topics in Chiropractic 1 & 2 *(Research development)* |
| **CHIR 931 & 932** | Diagnosis & Management 1 & 2 |

Since 2010, the structure of the anatomy units that are taught within the BChiroSc have not undergone any major changes. The structure of the chiropractic program at MQU means that the students have their formal anatomy instruction in the first two years of BChiroSc and the MSKanat component at the end of year one (Hlth109 – Anatomy of limbs and back) and start of year two (Hlth213 – Head, Neck and Trunk) of BChiroSc.

The current anatomy curriculum offered in the CD at MQU was designed with the primary goal of providing the chiropractic students with the anatomy they needed to form the basis of their clinical studies, while also catering to students not enrolled in the BChiroSc. In recent years MQU has increased the number of programs offered that include anatomy units. Due to this, the anatomy units offered by the CD has had increased enrolments from students outside of the BChiroSc. However, the BChiroSc is the only program at MQU that has the requirement for the students to study all the anatomy units offered by the CD. As such they are designed to have horizontally integrated learning with the other BChiroSc subjects such as physiology and chiropractic techniques, as well as vertical integration throughout the BChiroSc and MChiro2. The latter was strongly emphasized and controllable because all the relevant units were delivered from the same department.

Students begin in year one of the BChiroSc with one semester of introductory anatomy followed by one semester of limbs and back anatomy. In year two they have one semester of head, neck and trunk anatomy followed by one semester of neuroanatomy (Table 6.2.01). These anatomy units follow a similar format. Each has three hours per week of lectures followed by a two-hour lab-based practical and a one-hour tutorial. The lectures are largely didactic in presentation but include references to clinical application of knowledge or relevant examples of pathology for relevance. Laboratory practical classes are majority self-directed sessions with tutors and demonstrators available for assistance. Resources include anatomical models and for HLTH109 (Anatomy of limbs and back), HLTH213 (Anatomy of head, neck and trunk) HLTH 214 (Neuroanatomy) also dissected embalmed cadavers (prosections), X-rays/CT and MRI scans. Students have a locally produced workbook, based on learning outcomes, to answer questions and instructions to aid identification of structures. Students are also advised to purchase an appropriate anatomy text book and atlas.

Tutorials are classroom based and involve surface anatomy and case-based questions to answer with the assistance of a tutor. Students are also supported with a variety of digital resources through a Moodle based platform (iLearn) including digital atlases, 3D atlases, links to anatomy videos and formative quizzes.

Throughout the program and especially in the postgraduate years as students learn clinical skills such as muscle testing, nerve tension tests, joint manipulation and orthopaedic examination, there is revision of anatomical material as it becomes combined with clinical application of the anatomical knowledge. MSKanat is revisited in several units, particularly in year two of the BChiroSc, with the introduction of kinesiology and manipulative skills and later, in the first year of the MChiro2 with the introduction of units containing orthopaedic examination and rehabilitation (Table 6.2.03).

| Table 6.2.03 Anatomy revision and clinical application total hours at MQU | | |
|---|---|---|
| ***Unit*** | *Hours of lectures anatomy revision/ patho-mechanics/ orthopaedic testing/ pathology/ kinesiology/ biomechanics of upper and lower limb* | *Hours of clinical/ orthopaedic testing/ manipulation of upper and lower limb anatomy* |
| **CHIR 213 & 214** | 28 | 30 |
| **CHIR 315 & 316** | 0 | 4 |
| **CHIR 873 & 874** | 50 | 28 |
| **CHIR891 & 892** | 0 | 26 |
| **Total** | 78 | 92 |

### 6.3 Population of the Study

The focus of this study was on changes in students' anatomy knowledge from the start of the BChiroSc program, through to the end of the MChiro2 program. Therefore, the data only included participants that were enrolled in the BChiroSc from the first year and then continued into the MChiro2. In that regards, the two programs were regarded as five continuous years of study and the year groups referenced according to those year groups (Table 6.3.01).

| Table 6.3.01 BChiroSc and MChiro2: A five-year program. | |
|---|---|
| ***Program*** | *Year level* |
| **BChiroSc** | 1 |
| | 2 |
| | 3 |
| **MChiro2** | 4 |
| | 5 |

Participants were excluded from the study if they had studied MSKanat at MQU prior to 2010, as this was when the current curriculum commenced. Exclusion also applied to those that had studied MSKanat at another university and those that were enrolled in the MChiro3 as they would not have studied the same subjects as the students who completed the BChiroSc.

## 6.4 Instrument

### 6.4.1 Assessment of anatomy knowledge retention at two different cognitive levels

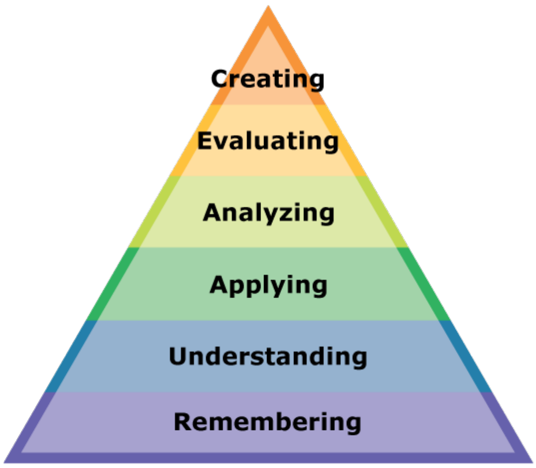
To measure the students' anatomy knowledge retention across all 5 years of the program, an anatomy test was developed (Appendix 11.02). In addition to measuring the level of anatomy knowledge retention, this study aimed to examine the effect of vertical integration and clinical application on the ability to apply that anatomy knowledge in a clinical capacity. To measure these potential changes in cognitive ability, Bloom's Taxonomy was applied to the anatomy questions. Considerations for the design of anatomy test included the questions:

- Had high levels of inter-examiner reliability.
- Measured anatomy knowledge at two different cognitive levels.
- Were indicative of the type of anatomy required by a registered chiropractor in Australia.

The first consideration was addressed by using multiple-choice questions (**MCQ**) which enabled reproducible and unbiased marking. In addition, it utilised a combination of the two forms of measures used to test knowledge retention, cue recall (student provides information they have learnt previously) and recognition (students have a sense of familiarity when they encounter information they have learnt before)[22, 78]. The third measure of retention, relearning (a measure in the differences in time it takes to relearn material)[78], was deemed not suitable to this study.

The second consideration was addressed with the adaptation of Bloom's Taxonomy to the anatomy questions. Recent editions of Bloom's Taxonomy include six categories/levels for educational goals (Figure 6.4.1.01)[79]. Although there are six categories to Bloom's Taxonomy, the two highest levels, evaluate and create, do not apply to the anatomy education discipline. However, the two higher levels are especially important to promote reflective practices particularly on ethical issues in anatomy and medical practice[80]. Thompson et al.[44] published in 2015 the Blooming Anatomy Tool (**BAT**). This is a specific set of criterion (Appendix 11.01) that guide the development of anatomy MCQ into four levels of Bloom's Taxonomy. Through validation of these criteria by the authors, it was determined that the highest inter-examiner reliability was when the four cognitive levels of Bloom's Taxonomy was simplified into two levels, low and high order question. As such, remember and understand were considered low order (LO), while apply and analyse were considered in the high order (HO) category.

**Figure 6.4.1.01 Bloom's Taxonomy Cognitive Levels**




The third consideration was addressed with the assistance of the Council Chiropractic Education Australia (**CCEA**). The CCEA is the governing body that assess chiropractic programs to qualify them for accreditation. While anatomy curricula within these chiropractic programs need to achieve the minimum standards set by the CCEA to attain accreditation, there is no core curriculum of anatomy in chiropractic within Australia. There is also no isolated measure of a student's anatomy knowledge as part of final examinations to graduate from the MChiro2 or MChiro3. The only circumstance anatomy knowledge is tested for a chiropractor wishing to gain registration in Australia, after the completion of their studies, is if they have studied in a non-English international program. As such, the only benchmark for what anatomy knowledge is deemed clinically relevant for chiropractors in Australia are these exams developed and given by the CCEA to chiropractors that have usually had some clinical experience.

For this study, a request was made to the CCEA for a sample set of these questions. The request was granted on the provision that the sample questions were not made publicly available.

Using the criteria outlined in the BAT and the sample CCEA questions as a benchmark for clinical relevance, a set of thirty multiple-choice MSKanat questions were developed. The questions were limited to MSKanat of the upper and lower limbs to ensure all year levels had been taught the anatomy. The questions included fifteen specific to upper limb and fifteen to lower limb

MSKanat. Each anatomical region contained a mixture of questions deemed by the author of the questions to be LO or HO cognitive levels according to the BAT.

These questions were developed by the author of this thesis who is a registered chiropractor with seven years' experience, and an anatomy lecturer and tutor with eight years' experience. The questions were then validated by an external panel who had no input in development of the questions. The panel consisted of five chiropractic academics, two anatomy academics and five students who had previously studied MSKanat at MQU in the past twenty-four months, who were not enrolled in BChiroSc or MChiro2. The panel members were asked to independently validate the exam questions for readability and categorisation into LO or HO cognitive categories. Each member of the panel was supplied with the BAT MCQ development guidelines and asked to assess each question into LO or HO according to the BAT criteria. No indication was given to the panel members regarding which cognitive level each question was designed for. The results from each panel member were collated. Questions required ninety percent agreement between panel members as to their categorisation into low or high order levels to qualify the question to be included in the final test. The results of the validation process resulted in the exclusion of ten questions and the remaining twenty questions were included in the final exam. These questions were evenly distributed between upper and lower limb anatomy and within those categories, into LO and HO cognitive levels (Appendix 11.02).

Different cognitive level questions do not equal the level of difficulty. Following the CCEA standards, all questions were made of high difficulty. This made the test at some discord with typical undergraduate tests which typically include a combination of questions of varying difficulty.

### 6.4.2 Assessment of student perception of units in the program contributing to their musculoskeletal knowledge retention

A questionnaire was developed to assess students' perception of where MSKanat learning was integrated, horizontally and vertically, within the curriculum. The questionnaire utilised a five-point Likert scale of importance using the International Association for Medical Education (**AMEE**) guide number 87 [81]. The students were asked to rate the units they had completed on how important the unit was for their MSKanat knowledge retention. The scale ranged from very to not important (Appendix 11.03). Subjects known to have no anatomy correlation such as radiographic physics and chemistry were excluded.

## 6.5 Data Collection

The chiropractic program teaching period is primarily in semesters one and two of the year, with only some basic science units having a repeated offering during a newly introduced, additional trimester. MQU is structured to have primarily two teaching sessions of thirteen-week semesters. Units that contain a practical component utilise the thirteenth week of semester primarily for practical examinations, with the official examination period starting the week after.

Data collection was conducted in week twelve of the thirteen-week semester two in 2016. Week twelve was considered an ideal time to test retention of knowledge as it reflected each year group's knowledge towards the conclusion of that year's formal instruction and teaching.

Permission was sought from the conveners (coordinators) of each of the technique units of each year level to allow data collection during a scheduled class time. Students were provided with the details and purpose of the research in their class and were given the opportunity to participate. The scheduled tutors were asked to hand out the test and the survey to those wishing to participate. The tutors were instructed to invigilate those participating in a controlled examination environment. Attendance for these classes has an attendance requirement but as attendance will not influence their final passing grade not all students from each year level were present for the data collection. Participants did not have any warning or knowledge that a test was being conducted and were therefore unable to prepare in anticipation of the test.

## 6.6 Statistical Analysis

The comparative analysis of the test results was conducted on three sets of measurements. The measurements included the number of correctly answered LO questions, HO questions and the total score.

- Descriptive analysis was done on all groups of measurements.
- One-way analysis of variance (**ANOVA**) was used to compare each of these measurements from each year group. The data was tested for equal variance using the F-test from the ANOVA and confirmed with the normal probability plot. A p-value of 0.05 was used to assess for significant difference and was based on the F-test from the ANOVA.

- Fisher's individual tests for differences of means was used to assess statistical difference between pairs of year groups. This information was also grouped using the Fisher least significant difference method with a 95% confidence interval[82].

The student survey results were collated using a numerical value replacing the descriptive point on the 5-point Likert scale used (Table 6.6.01). Descriptive analysis was conducted and the mean values were collated in a table.

| Table 6.6.01 Numerical values assigned to descriptive points on 5-point Likert scale of importance | | | | | |
|---|---|---|---|---|---|
| ***Description*** | *Very important* | *Quite important* | *Moderately important* | *Slightly important* | *Not important* |
| **Numerical value** | 1 | 2 | 3 | 4 | 5 |

### 6.7 Conflict of Interest and Risk of Bias

In addition to being a Masters of Research student, the author of this thesis has also been an anatomy lecturer and tutor at Macquarie University since 2009 and has tutored many of the participants involved in this project. To avoid any risk of bias the tools used in this project underwent scrutiny and validation from a panel. The format of the exam being multiple-choice removed any risk of bias in marking.

### 6.8 Ethics Approval

The Macquarie Human Research Ethics Committee granted ethics approval on 27 October 2016 (Reference number: 5201600656) (Appendix 11.04).

The execution of the data collection was assessed by the ethics committee and included the following considerations to avoid conflict of interest:

- Participation was completely voluntary and anonymous with no identification assigned to the test paper prior to completion. In the process of marking papers were assigned an identifying number so that data could be entered and crosschecked;
- The test was carried out in a controlled environment during chiropractic technique classes for each year group. The participants scheduled tutors, who were not involved with this study, were responsible for invigilation to avoid answer sharing and for collection of the papers.

## 7 THE RESULTS

A total of 387 students were enrolled in the MQU chiropractic program, out which 258 (67%) participated in the study. The response rate for individual years is given in Table 7.01.

**Table 7.01 Summary of responses for each year level.**

| Year level | Number of students enrolled | Test (numbers/percentage) | Survey |
|---|---|---|---|
| **1** | 89 | 61 (68.5%) | 53 (59.6%) |
| **2** | 64 | 46 (71.9%) | 36 (56.2%) |
| **3** | 72 | 51 (70.8%) | 48 (66.7%) |
| **4** | 83 | 56 (67.4%) | 48 (57.8%) |
| **5** | 79 | 44 (55.7%) | 44 (55.7%) |

### 7.1 Test Results

#### 7.1.1 Totals across years

The total marks from each test, collated across all year levels, appears to have a reasonably normal bell curve with a normal distribution of total marks from this exam (Figure 7.1.1.01). The distribution of results of the LO questions has a centered curve (Figure 7.1.1.02) with a median mark of five compared to the HO results which has a lower median of three with a curve slightly skewed to the right (Figure 7.1.1.03).

**Figure 7.1.1.01 Test Score Totals (LO+HO) Across All Years**

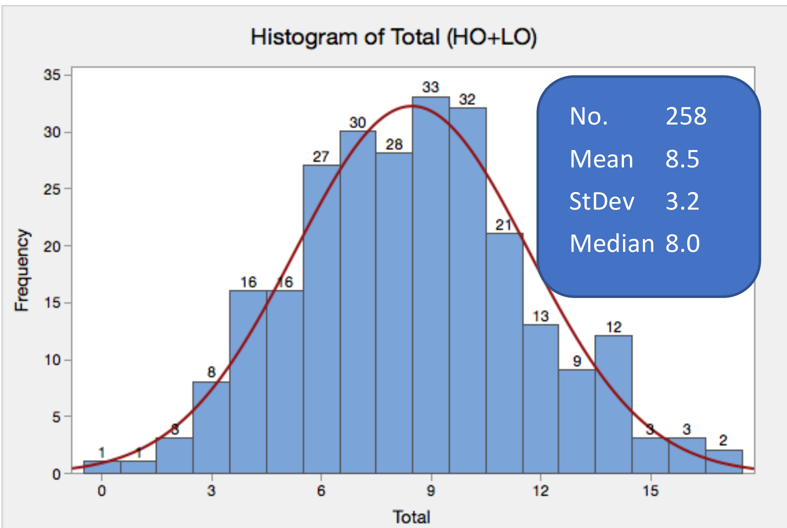


**Figure 7.1.1.02 Test Scores for Low Order Questions Across All Years**

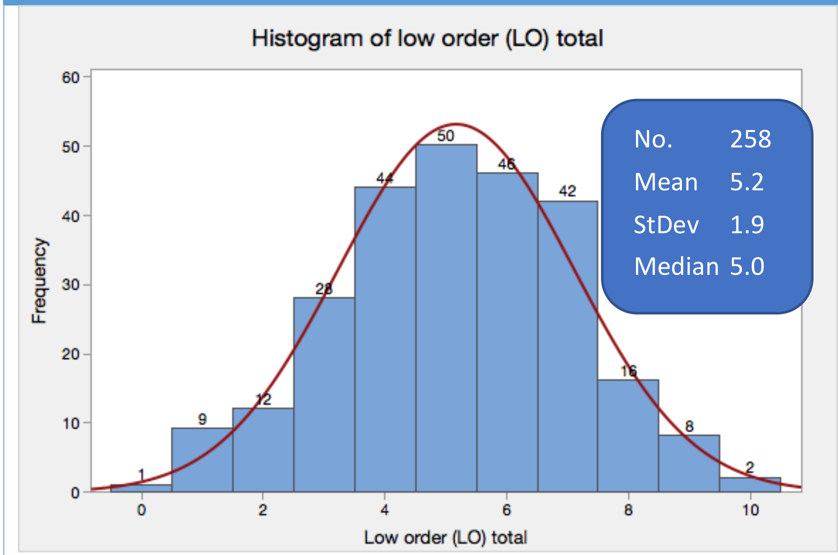
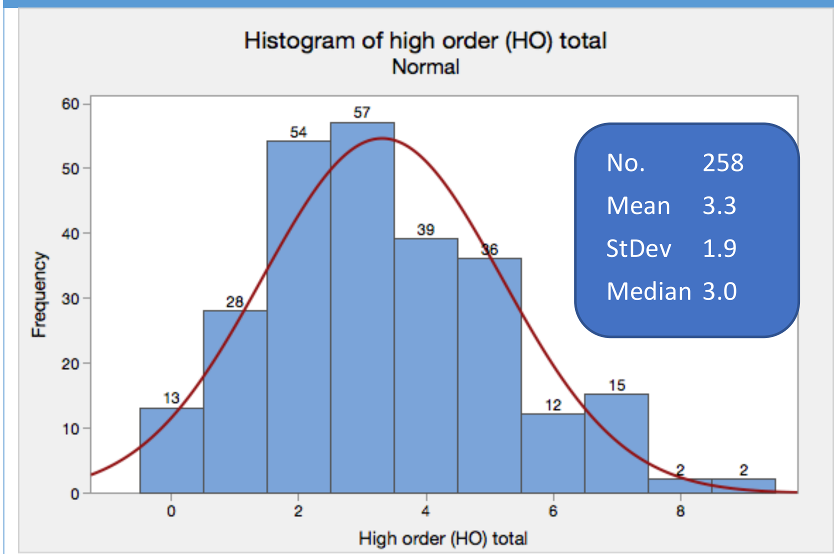



**Figure 7.1.1.03 Test Scores for High Order Questions Across All Years**




### 7.1.2 Comparison between year groups

The data demonstrated normal probability plots for comparisons of totals, for HO and LO questions across year groups confirming the normal bell curves and equal variances. The p-values for all three comparisons, based on the F-test from ANOVA, showed a significant difference (p-value <0.0001) between the means of the total marks, LO and HO questions of the exam across the five years. The spread of marks can be seen in Figure 7.1.2.01 and Figure 7.1.2.02.

**Figure 7.1.2.01 Test Scores by Year for Total Scores**

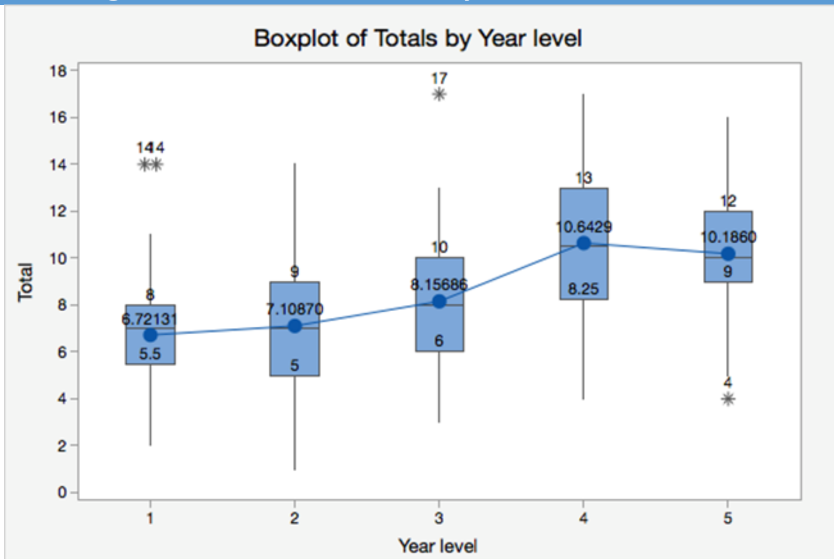
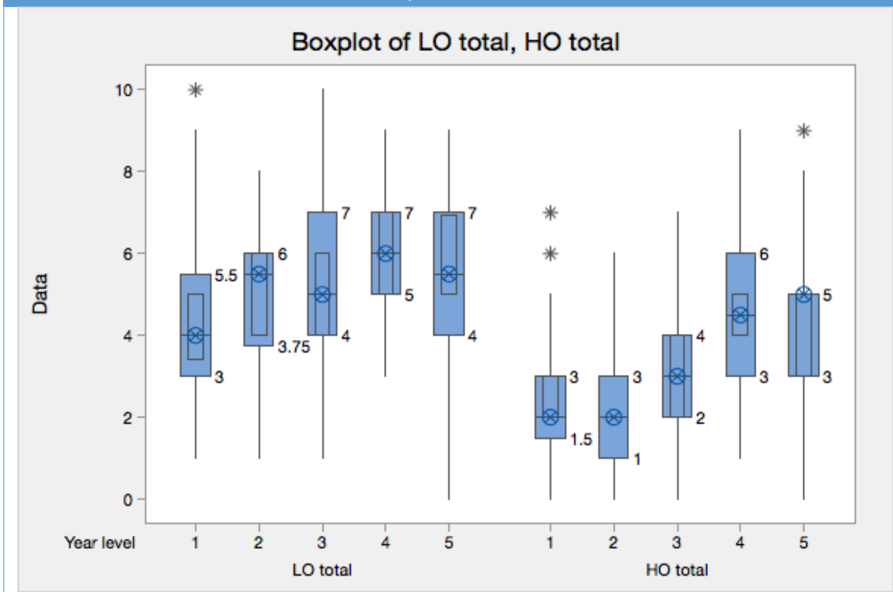



**Figure 7.1.2.02 Test Scores by Year for both High and Low Order Questions**




### 7.1.3 Total scores per year group

The means and medians of the total scores results can be seen in Table 7.1.3.01.

There was a significant increase in the means and medians of the total scores by each year group. Year one (**Y1**) had the lowest mean of 6.7 of a potential 20 marks. Year four (**Y4**) had the highest mean of 10.6. The Fisher pairing method of least statistical differences (Table 7.1.3.02) demonstrates an overlap of similarity between Y1, year two (**Y2**) and year three (**Y3**). However, Y1 was significantly different to Y3 and Y2 was similar to both Y1 and Y3. Y4 and year five (**Y5**) were significantly similar, but were different to all other years.

| Table 7.1.3.01 Statistics of Total Scores | | | | |
|---|---|---|---|---|
| *Year level* | *Mean* | *Standard Deviation (StDev)* | *95% Confidence Limits* | *Median* |
| *1* | 6.7 | 2.5 | (6.0, 7.4) | 7.0 |
| *2* | 7.1 | 2.7 | (6.3, 7.9) | 7.0 |
| *3* | 8.2 | 2.8 | (7.4, 8.9) | 8.0 |
| *4* | 10.6 | 3.0 | (9.9, 11.4) | 10.5 |
| *5* | 10.2 | 2.6 | (9.4, 11.0) | 10.0 |
| Pooled StDev = 2.7 | | | | |

| Table 7.1.3.02 Fisher Least Significant Difference – 95% Confidence Total Scores | | | | |
|---|---|---|---|---|
| *Year level* | *Mean* | *Grouping* | | |
| *4* | *10.6* | *A* | | |
| *5* | 10.2 | A | | |
| *3* | 8.2 | | B | |
| *2* | 7.1 | | B | C |
| *1* | 6.7 | | | C |
| **Means that do not share a letter are significantly different.** | | | | |

### 7.1.4 Low and high order results

The means and medians of the LO results can be seen in Table 7.1.4.01.

The means for the LO results demonstrate a different grouping pattern of statistical difference to the totals (Table 7.1.4.02). Y1 means are significantly different to all year groups with the lowest mean. There is a large grouping between Y2, Y3 and Y5 not significantly different from each other with Y4 significantly different from the group, but is not significantly different from Y5. The means ranged from 4.1 to 6.2 and the median ranges from 4.0 to 6.0 (Table 7.1.4.01). Y3, while having a higher mean (not significantly) to Y2, had a lower median score than Y2. In addition, Y3 had the largest standard deviation.

The large grouping between the year groups indicates that there is not a large difference between groups except for Y1 which had the lowest mean and median, and Y4 which had the highest mean and median.

| Table 7.1.4.01 Statistics of Low Order Scores | | | | |
|---|---|---|---|---|
| *Year level* | *Mean* | *Standard Deviation (StDev)* | *95% Confidence Limits* | *Median* |
| *1* | 4.2 | 1.9 | (3.8, 4.6) | 4.0 |
| *2* | 5.0 | 1.8 | (4.4, 5.5) | 5.5 |
| *3* | 5.1 | 2.0 | (4.6, 5.6) | 5.0 |
| *4* | 6.1 | 1.7 | (5.7, 6.6) | 6.0 |
| *5* | 5.7 | 1.6 | (5.1, 6.2) | 5.5 |
| Pooled StDev = 1.8 | | | | |

| Table 7.1.4.02 Fisher Least Significant Difference – 95% Confidence Low Order Scores | | | | |
|---|---|---|---|---|
| *Year level* | *Mean* | *Grouping* | | |
| *4* | 6.1 | A | | |
| *5* | 5.7 | A | B | |
| *3* | 5.1 | | B | |
| *2* | 5.0 | | B | |
| *1* | 4.2 | | | C |
| Means that do not share a letter are significantly different. | | | | |

The means and medians of the HO results can be seen in Table 7.1.4.03.

The median of the HO scores increased from Y1 and Y2 at 2 (Table 7.1.4.03) to the highest at Y5 with 5 out of a potential 10. The means of the totals ranged from 2.2 in Y2 to 4.5 in Y4 and Y5.

However, even though Y4 and Y5 total results were higher than the groups from the bachelor program, the median results were 10.5 and 10 out of 20 respectively.

The Fisher LSD grouping method (Table 7.1.4.04) demonstrates that the HO scores for Y4 and Y5 means where not significantly different from each other, but were significantly different from all the other years.

The means of the HO questions demonstrated a different grouping pattern of significant difference between the year levels to both the total and the LO totals. For Y4 and Y5 HO means where not significantly different, but were significantly different from Y1 and Y3 which were significantly not different to each other. Y2 was significantly different from the Y1 and Y3 group but was not significantly different from Y1.

| Table 7.1.4.03 Statistics of High Order Scores | | | | |
|---|---|---|---|---|
| *Year level* | *Mean* | *Standard Deviation (StDev)* | *95% Confidence Limits* | *Median* |
| *1* | 2.5 | 1.5 | (2.1, 2.9) | 2.0 |
| *2* | 2.2 | 1.4 | (1.7, 2.6) | 2.0 |
| *3* | 3.0 | 1.4 | (2.6, 3.5) | 3.0 |
| *4* | 4.5 | 1.7 | (4.1, 4.9) | 4.5 |
| *5* | 4.5 | 1.9 | (4.1, 5.0) | 5.0 |
| Pooled StDev = 1.6 | | | | |

| Table 7.1.4.04 Fisher Least Significant Difference – 95% Confidence High Order Scores | | | | |
|---|---|---|---|---|
| *Year level* | *Mean* | *Grouping* | | |
| *5* | 4.5 | A | | |
| *4* | 4.5 | A | | |
| *3* | 3.0 | | B | |
| *1* | 2.5 | | B | C |
| *2* | 2.2 | | | C |
| **Means that do not share a letter are significantly different.** | | | | |

The difference between the LO and HO were calculated for each participant, the p-value based on the F-test from ANOVA was 0.0023. This demonstrated a significant difference between year groups of how each group scored in LO versus HO. The Grouping Fisher LSD Method with 95% confidence demonstrated large groupings between years (Table 7.1.4.05). Y2 had the highest difference between LO and HO scores. The difference between LO and HO for Y3 was significantly similar to Y2, Y1 and Y4. Y1, Y4 and Y5 had the lowest difference between the LO and HO scores.

| Table 7.1.4.05 Fisher Least Significant Difference – 95% Confidence<br>Difference Between Low and High Order Scores | | | | |
|---|---|---|---|---|
| *Year level* | *Mean* | *Grouping* | | |
| *2* | 2.8 | A | | |
| *3* | 2.1 | A | B | |
| *1* | 1.7 | | B | C |
| *4* | 1.6 | | B | C |
| *5* | 1.1 | | | C |
| Means that do not share a letter are significantly different. | | | | |

### 7.2 Survey Results

The averages of the responses from each year level can be seen in Table 7.2.01. Due to the assignment of numerical values to the responses on the Likert scale (Table 6.6.01), the closer the numerical value is to one the overall response of the year group is more accurately described as 'very important'. Most of the responses therefore fell somewhere between 'quite important' and 'very important'.

The units in the BChiroSc that received the highest averaged response, indicating lower perception of importance, across the years were the units BIOL108/115 (Human Biology and Genes to Organisms). These two units scored vastly differently to the other units. The next highest average was BIOL247/257 (Systems Physiology and Neurophysiology), followed by HLTH215 (Principles in Health and disease).

All other responses were reasonably similar and were considered of high importance for their MSKanat knowledge retention. In addition, responses across year levels were remarkably similar.

The units in the MChiro2 that received the highest averages and therefore the lowest perception of importance for MSKanat retention was CHIR918 (Physical and Functional Assessment) and CHIR919 (Clinical Management). These values were only marginally different to the other values. The averages for most other units were very close to one indicating a perception of very important.

| Table 7.2.01 Mean values of Survey responses | | | | | | |
|---|---|---|---|---|---|---|
| *Subject* | *Year 1 (53)* | *Year 2 (36)* | *Year 3 (49)* | *Year 4(51)* | *Year 5 (38)* | *Mean* |
| *Hlth108/109* | 1.6 | 1.6 | 1.4 | 1.5 | 1.3 | 1.5 |
| *Chir113/114* | 1.4 | 1.6 | 1.7 | 1.9 | 1.6 | 1.6 |
| *Biol108/115** | 3.7 | 3.7 | 3.2 | 3.3 | 2.9 | 3.4 |
| *Hlth213/214* | - | 1.3 | 1.3 | 1.1 | 1.2 | 1.2 |
| *Chir213/214* | - | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| *Biol247/257** | - | 2.8 | 2.1 | 2.6 | 2.4 | 2.5 |
| *Hlth215* | - | 2.1 | 1.7 | 1.7 | 1.9 | 1.9 |
| *Chir315/316* | - | - | 1.4 | 1.2 | 1.4 | 1.3 |
| *Hlth316/317* | - | - | 1.5 | 1.5 | 1.6 | 1.5 |
| *Hlth333* | - | - | 1.6 | 1.5 | 1.3 | 1.5 |
| *Chir873/874* | - | - | - | 1.2 | 1.1 | 1.2 |
| *Chir891/892* | - | - | - | 1.3 | 1.3 | 1.3 |
| *Chir919* | - | - | - | 1.9 | 1.6 | 1.8 |
| *Chir916/917* | - | - | - | 1.6 | 1.3 | 1.5 |
| *Chir918* | - | - | - | 2.5 | 1.8 | 2.2 |
| *Chir896/897* | - | - | - | - | 1.1 | 1.1 |
| *Chir931/932* | - | - | - | - | 1.2 | 1.2 |
| *Chir903/904* | - | - | - | - | 1.1 | 1.1 |

1 = Highly Important, 2 = Quite Important, 3 = Moderately Important, 4 = Slightly Important, 5 = Not Important

**Indicates units not developed and taught by the CD*

# 8 DISCUSSION

## 8.1 Discussion of Test Results

The anatomy test provided the main source of information to answer the primary question of this study. That is, *"what are the retention rates of musculoskeletal knowledge of chiropractic students studying the chiropractic program at Macquarie University?"* The test questions were specifically designed to answer both the primary and subsidiary Research Questions given in Section 2.0.

In this study, it was hypothesised that there would not be any gross attrition of anatomy knowledge over the year levels due to vertical integration with applied clinical chiropractic units/modules, but there could be an initial period of knowledge attrition after the initial learning of MSKanat in Y1. This initial attrition could potentially have continued until the end of Y3 and then reversed in Y4 after the start of the MChiro2. The Masters course involves a large integration of anatomy with clinical application when orthopaedics and clinical neurology are introduced.

The results did not support this hypothesis but instead demonstrated an incremental increase in the total scores throughout the program relating to retention of MSKanat knowledge rather than the hypothesised attrition. This is different to the results from studies that had examined basic sciences (as anatomy is often considered) where there was found to be an attrition of knowledge(7, 10, 22, 23). That attrition is usually the result of information not being revisited after the initial learning. However, it is consistent with other studies conducted on programs in which there is specific focus on vertical integration and clinical application of anatomy knowledge as well as CBL(27, 28, 38).

The lack of attrition after Y1 is potentially due to Y2 studies including vertically integrated MSKanat knowledge with the introduction of kinesiology of the limbs. It needs to be acknowledged however, that the complete lack of attrition of knowledge between Y1 and Y2 could also be due to a possible distortion of the Y1 data. This distortion may have occurred due to Y1 students being tested for this study in week twelve of the semester, prior to completing their first theory exam on upper and lower limb MSKanat. The process of testing has been shown to increase retention(53-55, 57) and the lead up to final examinations usually involves large amounts of dedicated study by students to review and consolidate their knowledge prior to being examined on it. As such, data collection prior to their first theory examination on this anatomy may have negatively influenced results from Y1, and if tested a few weeks later may have had higher results.

The results demonstrated that the means of the totals increased from Y1 to Y4 and then slightly decreased for Y5. However, the results of Y5 may be impacted by having the lowest participation rates compared to other year levels. The low participation rates in Y5 were due to poor class attendance at the time of the test, most likely due to high workloads and pressures on the final year students so close to the end of their studies and entry into the workforce.

While there was an overall significant difference across the year levels, not all year levels where significantly different to each other. The pairs of the means demonstrate which year levels are significantly similar, which reveals a pattern of change across the years.

The paired means for the totals of the year levels where there is no significant difference does not directly support the hypothesis. However, it does highlight the concept from which the hypothesis was founded. The pairing demonstrates an increase to the means of the totals from Y1 to Y3 is not significantly different, with some similarity between them. Whereas, there is a significant difference between those year levels to Y4 and Y5 (Figure 7.1.2.02). The similarity across the totals of Y1 to Y3 combined with the significant increase to Y4 and Y5 highlights two things.

1. There was no knowledge attrition through the BChiroSc, probably indicating the vertical integration within that program was successful in preventing attrition.
2. The significant increase from the BChiroSc to the MChiro2 indicates vertical integration is not only preventing attrition but is enhancing learning. This is most probably due to anatomy being clinically applied in the form of clinical neurology and orthopaedic assessment in Y4 and clinical internships commencing at the end of Y4.

The significant increase in results from the BChiroSc to the MChiro2 demonstrate not only the importance of vertical integration in preventing attrition but also the 'rebound learning' that Magid et al.[31] and Feigin et al.[37] describe. 'Rebound learning' refers to the scenario where information that may not have been adequately retained at an initial exposure, if re-exposed to that material, there will be much higher retention rates compared to if that initial exposure had not occurred. This is a strong argument to not rely too heavily on vertical integration as a substitute for initial anatomy learning. If vertical integration is regarded as a solution to reduced teaching time for anatomy learning in the early years of a program, with anatomy learning divided across the program, then the benefits of rebound learning on knowledge retention will not be achieved. Repetition is highly regarded as major contributor to knowledge retention rates[28, 30, 31, 36, 37, 53-55]. If 'rebound learning' can occur, with each exposure to material, students' knowledge retention will increase leading to much higher overall levels of anatomy knowledge.

There is discussion in the literature regarding students' overall knowledge of anatomy within various health disciplines[2, 3, 5, 20, 21, 32, 41]. It is considered that that the decline in overall hours dedicated to teaching anatomy in a curriculum, combined with changed teaching methods and curricula design and a shift away from traditional resources such as dissection have all contributed to students not having enough anatomy knowledge for their discipline[4, 20].

One concern, especially when related to anatomy education, is that the curricula in many institutions have been highly modified with new teaching methods and structure but without the evidence to support the effectiveness of these changes. One of the modern teaching methods that has been adopted in anatomy education, without validation of efficacy, is the introduction of CBL and, in its extreme form, the flipped classroom. With anatomy being an area of study containing vast amounts of information, teaching time has historically been used to present that information. CBL takes time away from that presentation and flipped classrooms takes it completely out of the classroom. While this creates active-learning and allows for development of higher cognitive thinking, the format raises concerns whether students still learn enough of the anatomy that they require for their professional practice[27, 28, 35, 38]. It needs to be considered that traditional educational principles like rote learning, memorisation and time-on-task may still hold high value in anatomy education[31, 36].

Numerous studies have sought to examine the anatomy retention rates in attempts to measure the effectiveness of these new teaching methods and new curricula. These studies have shown various outcomes as to how effective CBL and vertical integration is at compensating for reduced anatomy teaching hours[2, 27, 28, 35, 38]. However, it also needs to be considered that the goal of these teaching methods was not about relaying the same volume of content, but with empowering the students with additional skills. One such skill being the ability to apply the information they have learnt to bridge the gap between student and clinician. Therefore, it needs to be considered that measuring anatomy retention rates by testing pure anatomical content may not be an accurate measure of assessment of the complete learning the student has achieved. If the retention rates are not accurately measuring everything the student has learnt, it would therefore not adequately reflect the potential differences between the different teaching styles. As such no determination could be made as to whether it is a successful method of teaching anatomy or not.

This study did not seek to answer which teaching styles were preferable, or whether students knew enough anatomy. It would be a simple inference from the low means of the total results from each year group to conclude that the students do not know enough anatomy. However, the design of the exam did not have the normal format of a balanced exam that would include a combination of easy, mid-range and difficult questions to tier results to different assessment grades. Nor did it assess what a reasonable passable level would be. Instead, the questions contained material that was reasonably difficult but were tiered into different cognitive ability, with the intent to track the changes in the year groups' ability to answer the different levels of cognitive ability. As such it would be difficult to assess without setting a validated pass mark to the test if the students had an acceptable level of anatomy level. Nonetheless, considering the level of difficulty of the test, preliminary assessment of the median results from Y5 could potentially indicate that there is an acceptable level for this group.

As Humphreys et al.[(15)] demonstrated, the consolidation of anatomy knowledge continues into clinical practice with the recent graduates usually having higher retention rates of anatomy knowledge than students. With the increase in anatomy knowledge retention from the BChiroSc to the MChiro2 due to an increase in application of anatomy knowledge, it would be expected that the students' anatomical knowledge and their ability to apply it would also continue to increase after graduation. Therefore, the overall means of the totals would not reflect the anatomy retention of a clinician after graduation. Further investigation is needed to see how the retention levels at different cognitive levels would change after graduation.

Due to the design of the anatomy test categorising questions into low and high cognitive levels, the pattern of results across the year levels can be further assessed (Figure 7.1.2.02). While there was a significant increase of the means across the year levels within the low order questions, the pairing demonstrates a high degree of similarity in results between the years. Y1 was the only year level to be significantly different to the rest. However, as previously stated, the Y1 data could have been potentially distorted by the timing of the testing.

The increase of the means in the low order questions from Y2 onwards was not very significant. Apart from Y1, there was very little change across all year levels in the students' low order cognitive anatomy knowledge retention. This disproves the hypothesis that there would be attrition of this knowledge throughout the chiropractic program. However, it is a positive finding as it demonstrates that the structure of anatomy integration within the chiropractic program at Macquarie University is sufficient for avoiding attrition of clinically relevant knowledge. This is consistent with McBride and Drake's[38] longitudinal study on retention of anatomical knowledge in a program specifically designed with vertical integration and CBL.

Given there was a significant change and pattern in the means of the total questions answered correctly, the lack of any great change in low order means indicates that a substantial portion of this change in the totals was due to significant increases in the means of high order questions. This is an important finding as it indicates the greatest change in knowledge retention across the year levels is an increase in higher cognitive ability, indicating that the retention across cognitive levels is not uniform. Development of higher cognitive ability is a critical development for students in a program aiming to teach clinical reasoning skills. Therefore, it is imperative to measure the changes that occur through a program in higher cognitive ability and distinguish the changes in HO from increases in total questions answered due to rebound learning because of successful vertical integration of MSKanat.

The pattern to the changes of the means of the high order questions demonstrates a similar pattern of change to the totals. However, while both share a significant difference between year levels in the BChiroSc and the MChiro2, there are some differences to the patterns.

The first difference is Y5 having a higher median score in the high order questions than Y4. While not statistically significant, it could be the influence of Y5 having had one year of clinical internship. Knowing that knowledge retention increases when material is actively recalled and revisited, Y5 may have had the advantage of having seen patient presentations during their clinical internships that have required them to recall, integrate and apply their MSKanat knowledge in their diagnosis and treatment. This would lead to an increase in their ability to answer the higher cognitive questions.

The second and unexpected difference, was Y1 scoring higher than Y2 in the high order questions. While this difference was not statistically significant in these result, further investigation is warranted to determine if Y1 could have performed better in this test if they were assessed after their first upper and lower limb MSKanat theory examinations. If Y1 results were affected by the timing of the test, then Y1 could have potentially scored even higher than Y2, making the difference between Y1 and Y2 HO scores significant. If there is a significant difference between Y1 and Y2 in their ability to apply MSKanat knowledge at a higher cognitive ability, it would indicate there is attrition of this ability between Y1 and Y2. This is despite Y2 having a significantly higher result in the low order questions compared to Y1.

The difference in high order results between Y1 and Y2 performance is highlighted when assessing the differences between low and high order means for each year group. In addition to comparing mean results of LO and HO scores between year levels, a greater difference is revealed when assessing each year levels relative scores in their LO and HO scores. Out of all year groups Y2 had the highest difference between its low and high order questions. Y1 had a significantly lower difference between its low and high order results, which is more of a reflection of them not receiving high scores in either cognitive level. However, given Y2 scored lower than Y1 in high order scores, and has the highest difference in results between LO and HO scores, the assumption can be made that there is potentially an attrition between Y1 and Y2 in higher cognitive ability.

This attrition can only be identified when measuring the difference in scores of the low and high cognitive questions and was not reflected in the totals for the test. This attrition of high order cognitive ability carries far greater consequences to learning development, especially in higher education, than loss of content information. Course designers need to be able to measure this attrition specifically in high cognitive ability to be able to adapt the curriculum to rectify the attrition.

This finding emphasises the question raised by Morton et al.[35] about whether testing anatomy knowledge rates without defined measurement of knowledge at different cognitive levels is an accurate reflection of what a student has learnt, and the changes that occur to a students' learning within any educational program. The differences between the means of the low order and high order questions demonstrate the changes that occur throughout the program in the students' ability to integrate and apply what they have learnt. These changes in cognitive learning cannot be tracked when assessing total scores only, highlighting the need to measure anatomy knowledge retention at different cognitive levels.

If this difference in higher cognitive ability between Y1 and Y2 were significant, it could be attributed to differences in teaching methods utilised in the format of the formal anatomy instruction in limb MSKanat in Y1 and the chiropractic technique units in Y2 that integrate limb MSKanat. The unit in Y1 that formally teaches MSKanat of the limbs (Hlth109) utilises CBL during its tutorials requiring students to apply and integrate their knowledge. While MSKanat of the limbs is integrated clinically and applied in Y2 with the introduction of kinesiology, there is no regular implementation of applied thinking in the form of CBL. However, the application of MSKanat, in the form of learning muscle strength testing, joint movement and manipulation, can be credited for the increase in low order scores that are seen in Y2.

While this highlights the importance of CBL on development of higher cognitive ability and clinical reasoning skills there still needs to be consideration when implementing CBL into programs. Results from studies have indicated that CBL singularly is not enough to ensure adequate learning[36] and repeated testing can be more effective than repeated CBL alone[53-55].

Many authors comment that with changes occurring in the field of education, that it is important that changes are made with care. While there is strong evidence that there is benefit to many of these changes, the evidence also strongly demonstrates the many factors that potentially influence these changes. The biggest consideration that needs to be made when adopting changes to teaching is that their implementation is factored into the entire framework of the curriculum. Vertical integration and CBL, when adequately supported within the curricula, show positive results on MSKanat knowledge retention and can be measured to enhance the cognitive abilities of the student population.

As has been demonstrated, students' learning will not occur uniformly across cognitive levels. If anatomy knowledge retention levels are to be used as a metric for assessment of learning success due to curricula design and teaching formats, it is imperative that retention is measured at different cognitive levels. This will give researchers a detailed reflection of the learning development that is occurring and identify potential attrition in higher cognitive ability, that could be masked in normal testing due to rebound learning of anatomy content at a low cognitive level.

## 8.2 Discussion of Survey Results

As noted above, in an era of rapidly changing educational environments, measuring the impact of these changes is essential to shape future changes. While the MCQ test sought to quantify the knowledge retention and assess the impacts of vertical integration, the survey sought to measure the perception of the students.

The perception students have on their learning has become an important focus in modern, student-centred, education. Davis et al.[(83)] explored the perceptions of anatomy faculty members in the anatomy department of the University of Bristol, and the students enrolled in undergraduate anatomy units from this department. The study sought to quantify what the staff members and students perceived as the most valuable teaching methods and resources. The results highlighted that opinions between staff and students may not always align, which could impact the achievement of learning objectives.

It was hypothesised in this study that perceptions between year groups may differ. It was thought that students in the later years may have more insight into the relevance of material taught in the earlier years. In addition, the level of importance placed on a unit may differ as they might have a greater perspective of where anatomy content is vertically integrated within the curriculum. However, the results showed that this was not the case with very similar responses between the year groups. This is potentially due to the horizontal integration that occurs throughout the program. As students are learning MSKanat, the theoretical knowledge is immediately being reinforced in clinical subjects. This is therefore shaping students' awareness of clinical relevance and a recognition of the clinical application contributing to their retention of knowledge.

Another clear finding from this study was the perception of many units throughout the curriculum of having high importance to their MSKanat knowledge retention. This is a positive finding as it indicates that students can identify a high level of vertical integration of anatomy knowledge throughout the program. In addition, the perception of the Y4 and Y5 students is that the subjects in their later clinical years have high importance to their MSKanat knowledge retention. However, the high level of importance that students placed on the units in the MChiro2 does not reflect the hours identified in the MChiro2 as being directly related to MSKanat. This reveals that the students perceive other skill developments important for their anatomy knowledge retention in addition to the formal integration of MSKanat. For a profession which requires an in-depth detailed knowledge of the neuro-musculoskeletal system it is important for these students that are near to completion of their studies to have this consolidation and clinical integration of their MSKanat knowledge. It is important for all year levels to identify the clinical relevance of MSKanat as there is direct correlation between students' perception of clinical importance and retention of knowledge[27].

Repetition, integration and clinical relevance are critical factors Bergman et al.[36] and Davis et al.[83] identified that students perceive as important for their anatomy knowledge retention. The findings from the survey indicate that students can recognise the repetition, integration and clinical relevance of the MSKanat learning. As students within a chiropractic program perceive anatomy as highly important[46], their recognition that it is vertically integrated within a program will re-enforce this importance. Understanding the clinical relevance of anatomy has been shown to increase retention rates and be an important factor in learning for students[36]. If students can recognise the vertical integration of anatomy within their program, it will re-enforce the clinical relevance of the material, magnifying the effect of vertical integration and the increase the retention rates of MSKanat knowledge.

Contrary to most units in the MChiro2 being perceived as having high importance to the students' MSKanat knowledge was one unit (Chir918). This unit, taught in Y4, received a comparatively higher score indicating a perception of lower importance on MSKanat retention. This finding was surprising because the learning outline identifies physical and functional assessment, with a strong emphasis on rehabilitation of the musculoskeletal system, as part of its teaching. As this survey is asking for student perception, it is possible that the perception of this unit is confounded by other variables such as opinions on teaching methodologies and teaching staff. In addition, this unit has divisions that have different foci. It is possible that the students were not considering the whole unit and only focusing on the division where there is less integration of MSKanat in their response.

The survey, while extensive, is not a complete overview of the entire program as it did not assess units which were known to have no MSKanat knowledge integration. An important finding is that units that were not designed and taught by the CD, that were considered to have some MSKanat knowledge integration, were perceived by the students as not having as high importance to their MSKanat retention rates compared to the units taught by the CD. This could be important information for curriculum designers to consider in the future when assessing efficacy of student learning, that it may be of value to the program to consider developing their own units in these areas to tailor them to the needs of the chiropractic students.

The main findings of this survey indicate students perceive a high importance of units developed and delivered by the CD to their MSKanat retention. This is both in units that have specifically integrated MSKanat knowledge, and units that have indirectly applied MSKanat knowledge. This recognition of the vertical and horizontal integration, as well as the application in clinical skills may contribute to students' awareness of clinical relevance and therefore their retention of this knowledge.

### 8.3 Limitations

The cross-sectional design of this study was a major limitation due to the constraint of the length of this project. A longitudinal design would give a more accurate overview of the development of anatomy knowledge comprehension that a cohort experiences as they progress through the chiropractic program. However, the results from a longitudinal design would be influenced by repeated testing contributing to better retention of knowledge.

This study also falls into a common problem with educational studies where ethical considerations influence the study design. The results from this study are attempting to make generalisations for the entire year group. The participation rates varied between 56-72% for the anatomy test, and 36-53% for the survey. With subjects being invited to participate in classes that did not have full attendance and participation being voluntary and anonymous there is no way of measuring potential bias of results due to differences between students that chose to participate versus those that did not. There is the potential that the results were influenced by a larger number of higher performing students attending class the week before their practical exams and choosing to participate in the study. In addition, the cross-sectional design does not allow for factoring in for underachieving students who may drop out which would affect the scores for that year group. These factors could be addressed better in a longitudinal study but there are also greater implications for conflict of interest.

Another limitation was the limited design of the test only utilising theoretical MCQ's and the relatively small number of questions. While MCQ's eliminated potential bias in marking and increases inter-examiner reliability, it is not an extensive method of testing anatomical knowledge. Additionally, while twenty questions focused only on MSK limb anatomy is sufficient as an indication of retained knowledge, a larger number of questions should be considered in future studies to thoroughly assess knowledge.  Also, additional styles of questions, including ones based off imagery should be considered given the highly visual and spatial element of anatomy learning.

These findings are making generalisations on a cross-sectional study. Potentially some of these findings could be the result of cohort differences. However, since 2010 the entrance requirement has only differed between 80.00-80.55/100 on the standardised Australian Tertiary Admission Rank. Therefore, it could be assumed that there are minimal differences between cohorts.

# 9 CONCLUSION

Retention of musculoskeletal anatomy knowledge was measured in the chiropractic program at Macquarie University. It was found that retention of musculoskeletal anatomy knowledge increased throughout the program. While there was an incremental increase throughout the program, the greatest changes in retention were found from the BChiroSc to the MChiro2.

By measuring the knowledge retention at two different cognitive levels it was discovered that the greatest change to retention occurred in the higher cognitive level. This can be attributed to the vertical integration and clinical application of musculoskeletal anatomy knowledge that occurs throughout the program. The changes that occurred to retention at the low and high cognitive levels were not uniform and reveal potential areas of improvement for the program. The differences between the low and high order scores revealed changes that were not reflected when assessing total scores only. Therefore, measuring anatomy knowledge retention at different cognitive levels provides detailed evidence to accurately shape future curriculum and teaching changes more effectively than if based on total scores of a test.

The cross-sectional design of this study mean there are inherent variables that cannot be controlled. While these preliminary findings hold great value to other educational studies, it is important that these results are validated with a longitudinal study.

The results of this study provide the foundations for future investigations focusing on changes to anatomy knowledge retention at different cognitive levels. Comparisons should be conducted on the changes that occur to knowledge retention between institutions, after students graduate and begin clinical practice and further into their clinical careers.

Measuring anatomy knowledge retention at different cognitive levels has been shown to be an insightful way of tracking cognitive changes between year levels within a program. It should therefore be considered as a standardised measurement in future anatomy educational studies.

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# 11 APPENDIX

## APPENDIX 11.01

## Blooming Anatomy Tool (BAT)

The Blooming Anatomy Tool (BAT)

| | Lower order | | Higher order | |
|---|---|---|---|---|
| **Bloom's level** | **Level 1 (Knowledge)** | **Level 2 (Comprehension)** | **Level 3 (Application)** | **Level 4 (Analysis)** |
| Distinguishing features of questions | • Questions are straight forward with answers likely stated verbatim in notes or text<br>• Question usually not placed in a clinical context<br>• Students not required to make independent connections from the information | | • Anatomic information may be placed in a clinical scenario or a new setting (although not all clinical questions are higher order)<br>• Students must interpret and make independent connections from the information | |
| Key skills assessed | Identify, recall, repeat, memorize | Describe or distinguish | Infer or predict | In addition to infer or predict: interpret, judge, critique, or analyze |
| Types of anatomical information assessed | • Basic definitions<br>• Facts<br>• Straightforward recall | • Anatomical concepts<br>• Basic spatial organization<br>• Basic understanding of pathways, blood supply, and innervation | • Interaction between two or more body systems<br>• Functional aspects of anatomical features beyond memorization | • Interaction between two or more body systems and applying information to a potentially new situation<br>• Interpretation of anatomical images<br>• Potential to use clinical judgment |
| Characteristics of multiple choice questions | • Only requires information recall<br>• Student may memorize answer without understanding process<br>• Knowing the "what" but not understanding the "why" | • Straightforward question, but more than a simple definition<br>• Visualization of a region<br>• Image questions asking to ID a structure without requiring a full understanding of the relationship of all of parts | • Apply information in a new context<br>• Connect multiple pieces of information independently (ex. several "steps" or "links" with the data must be understood in order to answer the question correctly)<br>• No clinical judgment is required | • Using information in a new context<br>• Possibility for clinical judgment<br>• Student required go through multiple "steps" and apply those connections to a situation<br>• Interpreting an image or data and applying information to a situation |
| Sample multiple-choice questions | The carpal tunnel is located deep to which of the following structures in the upper limb?<br>A. Palmar interossei<br>**B. Flexor retinaculum**<br>C. Extensor retinaculum<br>D. Cubital fossa<br>E. Thenar eminence | Which of the following structures passes through the carpal tunnel?<br>A. Deep branch of the radial nerve<br>B. Tendon of palmaris longus<br>**C. Tendon of flexor pollicis longus**<br>D. Deep branch of the ulnar nerve<br>E. Anterior interosseous artery | Pressure in the carpal tunnel would most likely affect which of the following?<br>A. Palmar interossei<br>B. Sensory innervation of the central palm<br>C. Movement of hypothenar muscles<br>D. Sensory innervation of the 5$^{th}$ digit<br>**E. Movement of thenar muscles** | A 60-year-old male presents to the hospital for a carpal tunnel release surgery. During the procedure, the surgeon accidently cuts the nerve traveling superficial to the flexor retinaculum. As a result, the patient would most likely have<br>A. Wasting of the thenar eminence<br>**B. Sensory loss to the central palm**<br>C. Weakness in wrist flexion<br>D. Sensory loss to the tip of the thumb<br>E. Weakness in adduction of the 2$^{nd}$ digit |
| Justification for scoring in example question | Requires only basic understanding of forearm/wrist anatomy. | Students must visualize structures located near the carpal tunnel and discriminate between distractors. | Two independent steps are required. Students must recall that the median nerve travels through the carpal tunnel and know what structures it innervates. | All steps described in the previous three questions are required. In addition, students must related detailed understanding of the anatomic organization of the region to a clinical presentation associated with nerve damage. |

**Note:** Bold face font indicates correct answers

## APPENDIX 11.02

### Anatomy Test

***Please circle the most correct answer to the following questions.***

1. Teres minor muscle will create what movement at the shoulder joint?
    a. Flexion
    b. Extension
    c. Medial rotation
    d. Lateral rotation
    e. Abduction

2. Fracture to the radial head causing damage to the nerve passing over the supinator muscle will most likely cause:
    a. Weakness to the wrist extensors
    b. Sensation loss over the anatomical snuff box
    c. Weakness to elbow extension
    d. Sensation loss to posterior forearm
    e. Weakness to wrist flexion

3. The most dorsal boundary of the anatomical snuff box is the tendon of:
    a. Extensor indicies
    b. Extensor digitorum
    c. Extensor carpi radialis longus
    d. Extensor pollicis longus
    e. Extensor pollicis brevis

4. Which of the following structures passes through the carpal tunnel?
    a. Flexor pollicis longus
    b. Extensor pollicis longus
    c. Flexor carpi ulnaris
    d. Palmaris longus
    e. Extensor pollicis brevis

5. Extensor carpi ulnaris will have the following movement at the wrist joint:
    a. Adduction
    b. Abduction
    c. Pronation
    d. Supination
    e. Circumduction

6. Which of the following structures passes through the cubital fossa?
    f. Radial artery
    g. Ulnar nerve
    h. Median nerve
    i. Triceps tendon
    j. Median antebrachial vein

7. Injury to the nerve as it travels through the tunnel of Guyon will most likely result in:
    a. Sensory change to the palm of the lateral side of the hand
    b. Weakness to flexion of the index finger
    c. Weakness to thumb opposition

d. Weakness to adduction of the wrist
e. Weakness to thumb adduction

8. Damage to the nerve resulting in weakness of brachialis muscle may also result in sensory loss to:
    f. Medial arm
    g. Lateral arm
    h. Posterior arm
    i. Medial forearm
    j. Lateral forearm

9. An opacity (indicating increased density) on an x-ray image around the greater tubercle of the humerus may indicate:
    a. A chronic injury of the biceps brachii tendon
    b. An acute injury of the supraspinatus tendon
    c. A chronic injury of the subscapularis tendon
    d. An acute injury of the subscapularis tendon
    e. A chronic injury of the supraspinatus tendon

10. A previous fracture to the distal humerus resulting in scar tissue formation in the cubital fossa and compression of the nerve travelling through there may result in:
    a. Weakness of wrist ulnar deviation
    b. Weakness of adduction of the thumb
    c. Weakness of proximal interphalangeal flexion
    d. Sensory change to the radial side of the forearm
    e. Sensory change of the hypothenar

11. The action of tibialis anterior is:
    a. Plantar flexion and eversion
    b. Plantarflexion and inversion
    c. Dorsiflexion and eversion
    d. Dorsiflexion and inversion
    e. Flexion at the knee

12. Damage to the nerve supplying sensation to the skin between the 1$^{st}$ and 2$^{nd}$ toe may also result in:
    a. Weakness in dorsiflexion
    b. Sensation changes to the skin over the medial calf
    c. Weakness in eversion
    d. Sensation changes to the skin over 5$^{th}$ metatarsal
    e. Weakness in plantar flexion

13. Which of the following structures passes through the tarsal tunnel?
    a. Tibialis anterior
    b. Tibialis posterior
    c. Dorsalis pedis
    d. Fibularis Longus
    e. Extensor digitorum longus

14. The tuberosity of the fifth metatarsal is an attachment for:
    a. Fibularis brevis
    b. Fibularis longus
    c. Fibularis tertius
    d. Tibilais anterior

e. Tibialis posterior

15. A football player is running in a straight line, and then suddenly turns to their right, but the spikes of their right foot remain anchored to the turf. A possible injury which may occur is:
    a. Biceps femoris tendon tear
    b. Semimembranosis tendon tear
    c. Fibular collateral ligament of the knee
    d. Anterior cruciate ligament
    e. Posterior cruciate ligament

16. The branch of sciatic nerve that could be entrapped if sensory symptoms are worsened by placing the ankle into dorsiflexion and inversion could be:
    a. Tibial
    b. Sural
    c. Superficial fibular
    d. Deep fibular
    e. Saphenous

17. The patella is a(n)
    a. Irregular bone
    b. Flat bone
    c. Sesamoid bone
    d. Long bone
    e. Short bone

18. Increased pressure in the anterior compartment of the leg is most likely going to affect:
    a. Plantar flexion of the ankle
    b. Sensation to the anterior aspect of the leg
    c. Extension of the great toe
    d. Eversion of the ankle
    e. Sensation loss of the dorsum of the foot

19. The ASIS is a muscle attachment for:
    a. Rectus femoris
    b. Vastus intermedius
    c. Tensor fascia latae
    d. Sartorius
    e. Pectineus

20. Compression of the nerve emerging from under piriformis may present as:
    a. Sensory change to the medial calf
    b. Weakness in hip external rotation
    c. Sensory change to lateral thigh
    d. Sensory change to the posterior leg
    e. Weakness to hip adduction

***HO questions numbers 2, 7, 8, 9, 10, 12, 15, 16, 18, 20.***

APPENDIX 11.03

Student Survey

**Section A – UNDERGRADUATE Program at Macquarie**

(If you did not graduate from the bachelor chiropractic program please progress to Section B - Postgraduate section)

***How important do you feel the following undergraduate units were for your musculoskeletal anatomy knowledge retention?***

*FIRST YEAR:*

**OTHER ANATOMY UNIT (HLTH108)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**CHIROPRACTIC SKILLS UNITS (CHIR113/114)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**BIOLOGY UNITS (BIOL108/115)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

*SECOND YEAR:*

**ANATOMY UNITS (HLTH213/214)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**CHIROPRACTIC SKILLS UNITS (CHIR213/214)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**PHYSIOLOGY UNITS (BIOL247/257)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**PRINCIPLES IN HEALTH AND DISEASE UNIT (HLTH215)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

*THIRD YEAR:*

**CHIROPRACTIC SKILLS UNITS (CHIR315/316)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**PRINCIPLES IN HEALTH AND DISEASE UNITS (HLTH316/317)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**CLINICAL DIAGNOSIS UNIT (HLTH333)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

## Section B – POSTGRADUATE Program at Macquarie

***How important do you feel the following postgraduate units were for your musculoskeletal anatomy knowledge retention?***

**NEUROMUSCULOSKELETAL DIAGNOSIS UNITS (CHIR873/874)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**CLINICAL CHIROPRACTIC UNITS (CHIR891/892)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**CLINICAL MANAGEMENT UNIT (CHIR919)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**DIAGNOSTIC IMAGING UNITS (CHIR916/917)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**PHYSICAL AND FUNCTIONAL ASSESSMENT UNIT (CHIR918)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**CLINICAL INTERNSHIP UNITS (CHIR896/897)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**DIAGNOSIS AND MANAGEMENT UNITS (CHIR931/932)**

☐ Very important ☐ Quite important ☐ Moderately important ☐ Slightly important ☐ Not important

**CLINICAL CHIROPRACTIC UNITS (CHIR903/904)**

| ☐ | ☐ | ☐ | ☐ | ☐ |
|---|---|---|---|---|
| Very important | Quite important | Moderately important | Slightly important | Not important |

APPENDIX 11.04

Ethics Letter

**Dear A/Prof Strkalj**

**RE: Ethics project entitled: "Musculoskeletal anatomy knowledge retention rates and students' perceptions of anatomy integration in curriculum: A cross-sectional study of Chiropractic students at Macquarie"**

**Ref number: 5201600656**

**The Faculty of Science and Engineering Human Research Ethics Sub-Committee has reviewed your application and granted final approval, effective 27th October 2016. You may now commence your research.**

**This research meets the requirements of the National Statement on Ethical Conduct in Human Research (2007). The National Statement is available at the following web site:**

**http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/e72.pdf.**

**The following personnel are authorised to conduct this research:**

**A/Prof Goran Strkalj**
**A/Prof Nalini Pather**
**Mrs Anneliese Hulme**

**NB. STUDENTS: IT IS YOUR RESPONSIBILITY TO KEEP A COPY OF THIS APPROVAL EMAIL TO SUBMIT WITH YOUR THESIS.**

**Please note the following standard requirements of approval:**

**1. The approval of this project is conditional upon your continuing compliance with the National Statement on Ethical Conduct in Human Research (2007).**

**2. Approval will be for a period of five (5) years subject to the provision of annual reports.**

**Progress Report 1 Due: 27th October 2017**
**Progress Report 2 Due: 27th October 2018**
**Progress Report 3 Due: 27th October 2019**
**Progress Report 4 Due: 27th October 2020**
**Final Report Due: 27th October 2021**

**NB. If you complete the work earlier than you had planned you must submit a Final Report as soon as the work is completed. If the project has been discontinued or not commenced for any reason, you are also required to submit a Final Report for the project.**

**Progress reports and Final Reports are available at the following website:**

**http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms**

**3. If the project has run for more than five (5) years you cannot renew approval for the project. You will need to complete and submit a Final Report and submit a new application for the project. (The five year limit on renewal of approvals allows the Committee to fully re-review research in an environment where legislation, guidelines and requirements are continually changing, for example, new child protection and privacy laws).**

**4. All amendments to the project must be reviewed and approved by the Committee before implementation. Please complete and submit a Request for Amendment Form available at the following website:**

**http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/forms**

**5. Please notify the Committee immediately in the event of any adverse effects on participants or of any unforeseen events that affect the continued ethical acceptability of the project.**

**6. At all times you are responsible for the ethical conduct of your research in accordance with the guidelines established by the University. This information is available at the following websites:**
**http://www.mq.edu.au/policy/**

**http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics/policy**

**If you will be applying for or have applied for internal or external funding for the above project it is your responsibility to provide the Macquarie University's Research Grants Management Assistant with a copy of this email as soon as possible. Internal and External funding agencies will not be informed that you have final approval for your project and funds will not be released until the Research Grants Management Assistant has received a copy of this email.**

**If you need to provide a hard copy letter of Final Approval to an external organisation as evidence that you have Final Approval, please do not hesitate to contact the Ethics Secretariat at the address below.**

**Please retain a copy of this email as this is your official notification of final ethics approval.**

**Yours sincerely,**
**Human Research Ethics Sub-Committee**
**Faculty of Science and Engineering**
**Macquarie University**
**NSW 2109**