LEARNING CROSS-SECTIONAL ANATOMY USING ULTRASOUND: PERSPECTIVES OF UNDERGRADUATE CLINICAL ANATOMY STUDENTS

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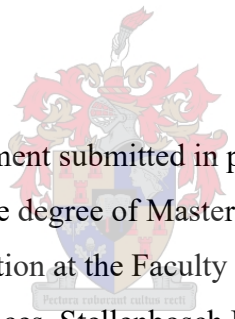

Research Assignment submitted in partial fulfilment of the requirements for the degree of Master of Philosophy in Health Professions Education at the Faculty of Medicine and Health Sciences, Stellenbosch University

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DECLARATION

By submitting this research assignment electronically, I, Janine Carla Correia, declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (except to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third-party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

December 2021

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Finally, I would like to dedicate this research assignment to my mentor, the late Dr Alwyn Louw: We are told that when we meet certain people, to hold onto them for dear life. However, what do we do when they are taken from us? We go on without them, our world is a little darker, but our lives are enriched. When a light goes off in this world, it turns on in another. The ripples you cast into the universe will never end and your kind-heartedness lives on in us who are still here.

ABSTRACT

Ultrasound (US) is increasingly used across the medical specialities as a diagnostic tool and as a result, medical faculties are being advised to further incorporate imaging into their programmes. Using US within undergraduate instruction has several benefits. The use of US, as a learning instrument, may strengthen existing anatomical knowledge and improve visual understanding of anatomy. The cost-effectiveness, as well as portability of the US, makes it a valuable means to add-on to traditional anatomy teaching modalities. Furthermore, students may develop skills in interpreting US images and ultrasound may add a different element to the study of anatomy.

The literature clearly shows evidence of the benefits of US in teaching anatomy, as well as the fact that anatomy educators can be trained by clinicians to incorporate US during dissection sessions. The value of US is evident from published works and will be worth investigating in the undergraduate setting. Furthermore, although US training may not always improve students' performances, it may lead to increased interest in learning anatomy for enhanced clinical practice.

The study aimed to explore undergraduate clinical anatomy students' perceptions on the use of ultrasound as an add-on to cadaveric dissection in the Division of Clinical Anatomy. The study population included the third-year undergraduate clinical anatomy students (25 students) at Stellenbosch University. The research question was aimed at obtaining students' perceptions about their views on the use of US in teaching and learning anatomy. To answer the research question, students were invited to participate in virtual focus group interviews. Three virtual focus group interviews were held following the US session with three to five participants in each; 11 participants volunteered to take part in the virtual focus groups.

The thematic analysis of the data obtained from the virtual focus groups was conducted and six themes were generated from the data. The six main themes are the study of living anatomy, learning cross-sectional anatomy, enhanced relevance of anatomy learning, increased interest in anatomy, instructional design and the affective and technical experience of using US.

The research demonstrated that it is feasible and advantageous to implement US sessions as an add-on to the teaching of anatomy during practical dissection sessions of undergraduate clinical anatomy students. The use of innovative technologies like US enhances the interest of students and allows them to develop dexterity and competencies in their learning process.

OPSOMMING

Ultraklank word toenemend onder die mediese spesialiteite gebruik as 'n diagnostiese instrument en gevolglik word mediese fakulteite aangeraai om beeld vorming verder in hul programme in te voeg. Die gebruik van ultraklank tydens voorgraadse onderrig het verskeie voordele. Die gebruik van ultraklank as 'n leerinstrument kan die bestaande anatomie kennis versterk en die visuele begrip van anatomie verbeter. Die koste-effektiwiteit sowel as draagbaarheid van ultraklank maak dit 'n waardevolle manier om saam met tradisionele anatomie-onderrig modelle te voeg. Verder kan studente vaardighede ontwikkel om ultraklank beelde te interpreteer, en ultraklank kan 'n ander element by die studie van anatomie voeg.

Die literatuur toon duidelik die voordele van ultraklank in die onderrig van anatomie, sowel as die feit dat anatomie-opvoeders deur mediese dokters opgelei kan word om ultraklank tydens disseksie sessies te gebruik. Die waarde van ultraklank blyk uit gepubliseerde werke en dit is die moeite werd om die gebruik daarvan in die voorgraadse studie te ondersoek. Verder, alhoewel ultraklank opleiding nie altyd studente se prestasies kan verbeter nie, kan dit lei tot verhoogde belangstelling in anatomie vir verbeterde kliniese praktyk.

Die doel van hierdie studie was om voorgraadse kliniese anatomie studente se persepsies oor die gebruik van ultraklank as aanvulling tydens kadawer disseksie in die Afdeling van Kliniese Anatomie te ondersoek. Die studie populasie het die voorgraadse, derdejaar kliniese anatomie studente (25 studente) aan die Universiteit Stellenbosch ingesluit. Die navorsingsvraag was gerig op die verkryging van studente se persepsies oor hul siening oor die gebruik van ultraklank in onderrig en leer van anatomie. Om die navorsingsvraag te beantwoord, is studente genooi om aan virtuele fokusgroep onderhoude deel te neem. Drie virtuele fokusgroep onderhoude is gehou na afloop van die ultraklank sessie met drie tot vyf studente in elk; 11 studente het aangebied om aan die virtuele fokus groepe deel te neem.

Die tematiese ontleding van die data verkry uit die virtuele fokus groepe is geanaliseer en ses temas is gegenereer uit die data. Die ses hooftemas is die studie van lewende anatomie, aanleer van dwarsdeursnee-anatomie, verbeterde relevansie van anatomie-leer, verhoogde belangstelling in anatomie, instruksie-ontwerp en die ervaring van die gebruik van ultraklank.

Die navorsing het getoon dat dit moontlik en voordelig is om ultraklank sessies te implementeer as 'n aanvulling in die onderrig van anatomie tydens praktiese disseksie sessies van voorgraadse kliniese anatomie studente. Die gebruik van innoverende tegnologieë soos ultraklank verhoog die belangstelling van studente en stel hulle in staat om vaardighede in hul leerproses te verwerf.

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LIST OF ABBREVIATIONS

2D	Two-dimensional
3D	Three-dimensional
4D	Four-dimensional
BSc	Bachelor of Science
CT	Computed tomography
HREC	Faculty of Medicine and Health Sciences, Health Research Ethics Committee
MRI	Magnetic resonance imaging
PLHET	Preparation, Linkage, Hook, Engagement, Transfer
QDA	Qualitative data analysis
SUNLearn	Stellenbosch University's Learning Management System
UG	Undergraduate
US	Ultrasound

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1. INTRODUCTION

This introductory chapter presents the foundation of this study. The chapter starts by presenting an overview of the layout of the research assignment. This is followed by the foundation within which this study was performed alongside the researcher's experience as an anatomy educator. The research questions motivated by the research significance are highlighted and the research aims, and objectives are described.

1.1 OVERVIEW

This research assignment consists of five chapters. In this introductory section (chapter 1), the motivation for this study is explained and an overview of the research assignment is presented. The literature review (chapter 2) considers the current knowledge in health professions education and will highlight the use of ultrasound in anatomical sciences education and the learning theory that underpins it. The chapter on methodology (chapter 3) focuses on the research questions, selection of study design, data considerations and recruitment. The methods section describes the processes that enabled the gathering of data, recruitment, and instructional format applied to analyse data. In the results and discussion chapter (chapter 4), the results from the virtual focus group interviews are presented and discussed with reference to the aim of the study. The concluding chapter (chapter 5) concentrates on the answers to the research questions and considers the importance of the study in the context of health professions education by highlighting the findings. The concluding chapter also includes strengths, limitations, and recommendations that provide suggestions for the implementation of future sessions and studies in this area.

1.2 FOUNDATION OF THE RESEARCH

Anatomy, the study of tissues, organs, and systems in the body, is an important module in the curricula of many health professions and has been a cornerstone in medical education throughout history (Turney, 2007; Louw, Eizenberg & Carmichael, 2009; Swamy & Searle, 2012; Sawant & Rizvi, 2015). Furthermore, anatomy is a unique, visual, high content-based, and practical course subject, which involves investigating and understanding three-dimensional anatomical structures (Turney, 2007). However, according to Turney (2007), there has been a shift from passive, instructive, extremely exhaustive anatomy courses towards clinically relevant anatomy courses. Consequently, it is especially important to find innovative ways to teach a high content-based subject, such as anatomy, as well as integrating clinical anatomy.

Anatomy is a challenging subject to teach and to learn. Firstly, anatomy includes numerous new concepts and words, making it a perplexing subject (Assis, Johnson & Prakash, 2019). Secondly, the latest trends in health professions education have led to decreased teaching time in anatomy (Louw, Eizenberg & Carmichael, 2009; Ganguly & Chan, 2008; Sawant & Rizvi, 2015). Thirdly, it is challenging to find and assess methods to instruct a diverse group of students more efficiently, in less time, and often with restricted resources. Lastly, modern health professions education has moved its focus from learning fundamental medical sciences in compartments towards integrated clinically applied anatomy (Kapur et al., 2016). These challenges further necessitate the finding of innovative ways to teach a challenging subject such as anatomy.

Clinical anatomy undergraduates spend a substantial number of hours in dissection halls and practical classes studying anatomy from prosections (previously dissected specimens), plastic anatomical models or by dissection during the undergraduate period (Ivanusic, Cowie & Barrington, 2010). However, purely covering the content in anatomy objectives with instructive lectures and practical dissection sessions may not be as effective to yield a long-term understanding of anatomy (Ganguly, 2010; Assis, Johnson & Prakash, 2019). According to Turney (2007), anatomy must discard the image of being out-of-date and implement various innovative teaching modalities, such as embracing the digital revolution, utilizing models, clinical relevance, body painting, and advanced imaging technologies. Anything that encourages interest in anatomy should be advocated and interventions that assist students to develop a better understanding of living and clinical anatomy should be pursued. Living anatomy is the study of anatomy revealed in living individuals and clinical anatomy refers to the study of human anatomy as it connects to clinical practice (Boon, Meiring & Richards, 2002; Ganguly & Chan, 2008).

One of the innovative teaching modalities includes imaging technologies. Imaging technologies can be used to observe the normal and the anatomical pathologies and variations (Sawant & Rizvi, 2015). Radiographs allow students to observe skeletal anatomy, while ultrasound (US) images permit students to visualize soft tissues and organs in real-time, which can be used to complement cadaveric dissection (Sawant & Rizvi, 2015). Alternatively, computerized tomography scans and magnetic resonance imaging assist particularly in the study of sectional anatomy, by transforming three-dimensional (3D) organs and structures into a two-dimensional (2D) layout (Ganguly, 2010; Sawant & Rizvi, 2015).

It is clear from the studies that anatomy learning remains a substantial part of the foundational sciences that must be successfully mastered, presenting considerable challenges to both students and educators. In my experience as an anatomy educator, students have difficulty developing an understanding of living anatomy and relating the basic medical sciences to their application in the

clinical realm. However, as an anatomy educator in this undergraduate (UG) programme, I consider it crucial to research innovative, exciting, engaging, and multimodal ways to motivate a proactive and deep approach to learning. US has the potential to offer a connection between students' comprehension of anatomy while learning basic medical sciences and their subsequent evaluation of actual patient anatomy in clinical practice.

The following sections aim to describe the problem statement, research aim, research question, and study significance. The literature review will specifically focus on the use of ultrasound in anatomical sciences education. The primary intention is to provide a thorough background to establish a clear rationale for the proposed study.

1.3 PROBLEM STATEMENT

Living anatomy, as an educational component, is a neglected entity in anatomical sciences education. Furthermore, students frequently find it demanding to visualize the functioning living anatomy of the human body therefore the implementation of ultrasound as an additional learning strategy may strengthen existing anatomical understanding and improve visual awareness of anatomy. Studies focusing on health profession students have demonstrated the beneficial effect of the inclusion of ultrasonography in undergraduate anatomy education (Stringer, Duncan & Samalia, 2012; Jurjus et al., 2014; Bullen et al., 2020). Currently, this teaching modality is not employed within the Division of Clinical Anatomy. The additional value of ultrasonography, in traditional curricula, thus merits further investigation.

1.4 RESEARCH QUESTION

What are the perceptions of undergraduate clinical anatomy students at the Faculty of Medicine and Health Sciences, Stellenbosch University on ultrasound as an imaging instrument to enhance the learning of cross-sectional anatomy?

1.5 RESEARCH AIM & OBJECTIVES

The aim of this study is to explore undergraduate clinical anatomy students' perceptions on the use of US as an add-on to cadaveric dissection in the Division of Clinical Anatomy.

In support of the aim of the study, the objectives of the study are to:

- Explore third-year undergraduate clinical anatomy students' experiences of utilizing US as an add-on to cadaveric dissections to teach living anatomy.
- Identify factors that influence students' learning of living anatomy when utilizing US as an add-on instrument to cadaveric dissection.

1.6 STUDY SIGNIFICANCE

Ultrasound is harmless, has the benefit of offering visualisation of anatomical structures and their functional anatomy in a non-invasive method, and is used frequently in practice and research (Swamy & Searle, 2012; Maher & Hale, 2015; So, Patel & Orebaugh, 2017). Ultrasound is increasingly used across the medical specialities as a diagnostic tool and as a result, medical faculties are being advised to further incorporate imaging into their programmes (Brown et al., 2012; Griksaitis, Scott & Finn, 2014). According to Maher and Hale (2015: e928), US of the musculoskeletal system used during the teaching and learning of anatomy, "brings anatomy to life" and highlights the clinical significance of why it is relevant to the students. The students welcome it and are enthusiastically involved during the sessions. Evidently, the US has a purpose outside of diagnostics (Maher & Hale, 2015).

Modern innovative educational methods to teach and learn anatomy are rapidly emerging. These include interactive multimedia resources such as YouTube, augmented virtual reality, virtual dissections, and imaging technologies (Bergman, 2015; Sawant & Rizvi, 2015). Although there is a paradigm shift in the teaching and learning of anatomy due to advances in the digital era and teaching methodologies, some authors still suggest that dissection is the preferred method to teach and learn anatomy (Turney, 2007; Ganguly & Chan, 2008; Bergman, 2015). In contrast, research has also suggested that dissection is not a standardized learning occurrence (Biassuto, Caussa & Criado del Río, 2006). Learners have different learning preferences in dealing with dissection, consequently involving differences in the quantity and quality of knowledge (Bergman, 2015). Thus, further motivating the incorporation of the US to teach and learn anatomy is essential.

The goal of the study is to explore undergraduate clinical anatomy students' perceptions of the use of ultrasound in anatomy. The outcomes will assist educationalists who are involved in teaching and learning anatomy to make informed decisions regarding the incorporation of ultrasound as an instructional strategy. Anatomy educators would also benefit from this study, as it may add a better understanding of how undergraduate students experience US for learning cross-sectional anatomy.

2. LITERATURE REVIEW

The literature review will focus on the use of ultrasound in anatomical sciences education and the learning theory that supports it. In this chapter, I present the literature on the benefits and challenges of US imaging in anatomy education. Also, the influence on the learning of including US in the anatomy curriculum on the study of surface and living anatomy, the clinical relevance of anatomy, and the understanding of spatial features are discussed. Lastly, I will investigate literature on who should teach these US sessions. The primary intention is to provide a thorough background to establish a clear rationale for the proposed study.

2.1 ULTRASOUND IN ANATOMY EDUCATION

2.1.1 Benefits and Challenges

Using US within UG instruction has several advantages. The use of US as a learning instrument may strengthen existing anatomical understanding as well as improve visual understanding of anatomy (Teichgräber et al., 1996; Brown et al., 2012; Patten, 2015; Kapur et al., 2016). The cost-effectiveness, as well as portability of the US, make it a valuable means to add-on to traditional anatomy teaching modalities (Brown et al., 2012). Furthermore, students may develop skills in interpreting US images and ultrasound may add a different element to the study of anatomy (Tshibwabwa & Groves, 2005; Griksaitis, Scott & Finn, 2014). According to Griksaitis, Scott and Finn (2014), the US illustrates living anatomy to students in a way not easily attained by dissection sessions. Ultrasound adds form and functions animatedly and emphasises the prospective clinical applications of the foundational sciences that the students must learn.

However, some challenges were recorded with the inclusion of US into a UG anatomy curriculum, for instance, limited curricular time, large cohort/class sizes, absence of trained clinicians in the cadaver laboratory, difficulty in interpreting the US images by untrained undergraduate students and an absence of available US devices assigned for educational use (Stringer, Duncan & Samalia, 2012; Allsop et al., 2021). To overcome these challenges, Stringer, Duncan and Samalia (2012) found that teaching anatomy through US, even without the student having a hands-on experience, reinforces the learning of clinical anatomy and provides students with a prologue to the clinical use of ultrasound. They demonstrated living anatomy through a 1-hour US session by projecting images on a big lecture theatre screen. The majority (80%) of the respondents considered the session as positive and perceived that it enhanced their knowledge of anatomy (Stringer, Duncan & Samalia, 2012). This study clearly indicates the benefits of US in teaching and learning anatomy by simply introducing students to US images without any hands-on training.

On the other hand, Knobe et al. (2012) compared three groups of medical students. Besides the obligatory dissection course, the arthroscopy group acquired anatomy knowledge through arthroscopy training, the US group through US training, and the control group only via cadaveric dissection. They found that medical students who received practical arthroscopy training to acquire anatomical knowledge performed moderately better in an anatomy multiple-choice examination compared to groups who received hands-on US training. The authors concluded that arthroscopy and US training might not significantly alter students' performances; however, it does have the potential to raise interest in clinical and surgical anatomy (Knobe et al., 2012).

Patten (2015) focused on the involvement of tutors and students in the use of US to lecture anatomy in the UG medical programme at Newcastle University. Students fully agreed that the US sessions helped to supplement their knowledge of anatomy they had previously acquired using different anatomical resources, such as prosections, plastic models, and cross-sectional images. In addition, according to Grant and May (2015), US training allows merging of previously learnt anatomical knowledge, appreciation of the integration of various anatomical systems and improvement of the appreciation of sono-anatomy. Sono-anatomy refers to anatomy as visualized with US (Heilo et al., 1997).

A recent study by Allsop et al. (2021) integrated US into the UG medical programme at the University of Bristol. The general student response was incredibly positive, and the students regarded the experience as valuable and enjoyable. However, the students perceived the anatomy difficult to identify because of unfamiliarity with the US scanning format, and students also had trouble understanding the positioning of the US image and the probe. Allsop et al. (2021) recommended that extra online learning materials with basic US principles could increase the students' preparedness for the sessions.

Although there are challenges in implementing US in an anatomy curriculum, much of the literature offers suggestions on how to deal with some of these challenges (Stringer, Duncan & Samalia, 2012; Griksaitis, Scott & Finn, 2014; Allsop et al., 2021). Griksaitis, Scott and Finn (2014) even offer a set of twelve guidelines on how to teach anatomy using US in an undergraduate medical curriculum. In this research project, I will also share my experience on how I managed these challenges as well as make recommendations for improvement in future US sessions.

2.1.2 Living Anatomy

The study of living anatomy has acquired popularity in anatomical science education during the last decade (Brown et al., 2012). Living anatomy is the anatomy displayed on living people (Ganguly,

2010). The most valuable instruments currently for the study of living anatomy are medical imaging devices, such as computed tomography (CT), X-ray, magnetic resonance imaging (MRI), and US (Ganguly, 2010). A study by Bowman, Lawson, and McKillup (2016) found that US is the favoured manner of delivery for living anatomy lectures in comparison to videos, radiological images, computer programmes, and dissection. According to the survey results from Bowman, Lawson and McKillup (2016), real-time US scanning was the most preferred method of medical imaging and medical sonography students for learning anatomy.

In another recent study by Birrane et al. (2018), the authors reviewed 128 articles and found that the implementation of US in undergraduate health professions education is practical and advantageous to students (Birrane et al., 2018). Furthermore, students perceived the usage of US in anatomy teaching as an innovative and creative method to motivate the learning of living clinical anatomy (Tshibwabwa & Groves, 2005; Birrane et al., 2018). Ultrasound also contributes to the comprehension of normal anatomy beyond what students have learnt through conventional teaching methods (Patten, 2015; Blackstock & Carmody, 2016).

2.1.3 Clinical Relevance

Health professions students, as prospective clinicians or clinical anatomists, are expected to relate their understanding of anatomy in medical imaging to clinical practice (Swamy & Searle, 2012). Sonography is a particularly appropriate link connecting basic and clinical sciences (Teichgräber et al., 1996). Swamy and Searle (2012) investigated the use of US to teach anatomy to medical students by including US teaching into anatomy dissection sessions of the upper and lower extremities. US demonstration was performed on a pre-scanned student volunteer who had granted informed permission. Afterwards, the students had the chance to make use of US and identify structures on each other. The results indicated that the students experienced US teaching as valuable and considered US to have enriched their comprehension of anatomy. Swamy and Searle (2012) concluded that the introduction to imaging technologies might increase confidence and prepare undergraduates for exposure to using US as a diagnostic tool throughout clinical practice.

A recent study by Rodríguez-López et al. (2020) investigated multimodal instruction, combining a 3D atlas, US, and the traditional didactic approach. The results suggested that students believed that the mixed methodology teaching approach that combined lectures, an anatomy atlas, a 3D atlas, and US had a constructive effect on their capacity to study anatomy as well as reinforce anatomical understanding and its clinical application. Furthermore, all the students considered this method valuable to enhance the clinical importance of anatomy (Gonzales et al., 2020).

A study by Dettmer et al. (2010) found that integrative teaching of anatomy with surgery and radiology is a helpful add-on to the traditional anatomy dissection sessions and can enhance the learning process. Although they did not include US, they found that the integration helped the students to obtain a different view of anatomy and an improved topographical appreciation of anatomy, and to learn anatomy that was relevant for future clinical practice. Therefore, to fully appreciate why the form and function of anatomical structures are important, and to guarantee sufficient retention of the information, the method of anatomy should ideally be combined with clinically relevant topics (Louw, Eizenberg & Carmichael, 2009).

2.1.4 Surface Anatomy

Surface anatomy is described as the study of the external anatomical aspects of the human body, features that can be examined by sight, without dissection, and the topographical position of anatomical structures in relation to the external anatomy (Sawant & Rizvi, 2015). Surface anatomy in conjunction with functional anatomy is important for conducting a physical examination of a patient, as well as performing clinical procedures (Louw, Eizenberg & Carmichael, 2009). Azer (2013) reviewed the literature regarding the position of surface anatomy in literature, especially the techniques employed in teaching surface and living anatomy and found that most anatomy textbooks include insufficient information. However, there has been an expansion in the literature addressing ways employed in teaching surface living anatomy, such as using a portable US (Ivanusic, Cowie & Barrington, 2010; Stringer, Duncan & Samalia, 2012; Swamy & Searle, 2012). Consequently, it would be worthwhile to investigate whether the participants in this study found that the US added value to their learning of surface anatomy.

In a recent study, Smith, Sharp and Dilley (2019) focused on students' experiences in learning anatomy through US. Findings of both survey responses and focus group discussions indicated that students found US useful for interpreting three-dimensional and radiological images and stated that it augmented their understanding of surface anatomy (Smith, Sharp & Dilley, 2019). With the growing use of ultrasound in practice, early use of US will certainly help prepare students for clinical practice (Brown et al., 2012; Kapur et al., 2016; Smith, Sharp & Dilley, 2019) as well as contribute to anatomy learning by "combining surface anatomy to cross-sectional anatomy" (Dreher, Dephilip & Bahner, 2014: 232).

2.1.5 Spatial Understanding

Spatial understanding is the ability to recognize 3D structures, remembering relationships among their parts and surrounding structures and the mental manipulation of objects (Bogomolova et al., 2020). According to Gonzales et al. (2020: 707), spatial understanding is "the cognitive capacity to understand and mentally manipulate concepts of objects, remembering relationships among their parts and those of their surroundings". Spatial understanding is a crucial factor in learning anatomy (Vorstenbosch et al., 2013; Gonzales et al., 2020). A recent study by Alexander et al. (2020) explored students' spatial understanding of human anatomy using US. Students participated in a didactic and a hands-on session with volunteers. Students were requested to complete an evaluation assessing their spatial understanding of human anatomy and their skill in finding anatomical structures utilizing US. The assessment results demonstrated considerable improvement in those skills. Based on the results, Alexander et al. (2020) concluded that US is a powerful educational device that can be implemented to assist students to understand anatomical concepts and spatial relationships. In addition, the outcomes of a study by Brown et al. (2012) showed enhanced student perception of the ability to locate structures using US and better conceptual comprehension of spatial relationships among anatomical structures.

Despite the benefits of the implementation of ultrasonography in anatomy education, a restriction is the capability to view anatomical structures and its surroundings in 3D according to Carter et al. (2017). Traditional US scanning is 2D, meaning it sends and receives US waves in just one plane. Carter et al. (2017) took it a step further and included a 3D/four-dimensional (4D) (4D is 3D imaging performed in real-time) US. Their study aimed to use US to find the thyroid gland on cadavers and living subjects and to obtain the medical students' perceptions on their experience using 3D/4D US. According to their data, most students perceived the 3D US to be better than the 2D US in the study of systemic anatomy. Consequently, it would be meaningful to see whether the implementation of 2D US in this study will be perceived as beneficial in enhancing spatial understanding of the clinical anatomy students.

2.1.6 Ultrasound Instructors

One of the challenges incorporating US in anatomy curriculum is the availability of trained clinicians with sonography experience. Patten (2015) effectively used minimally trained tutors to implement US in an undergraduate medical curriculum. Jurjus et al. (2014) also demonstrated that anatomists (with limited US training) were as efficient as clinicians in teaching anatomy using US, thus challenging the notion that trained clinicians are needed as instructors. Jurjus et al. (2014) compared students' appraisal of US anatomy teaching sessions by clinicians and anatomists. Before the practical

session, the clinicians taught anatomists how to use the US device. Results showed the medical students rated the two groups as similar. Also, no statistical difference was found on anatomy test scores between the anatomist-trained and clinician-trained groups. The results confirmed that anatomists can teach living anatomy through US accompanied by basic guidance in addition to clinicians (Jurjus et al., 2014).

2.2 AUTHENTIC LEARNING IN THE US CURRICULUM

Authentic learning refers to real-life challenges, their solutions, and students' potential to make sense of their attempts in the setting of their own lives and ethical practices (Lombardi, 2007; Pawlina & Drake, 2016). The notion underlying this method is that learners will discover what is significant to them and as soon as understanding has personal value, it is more deeply processed (Pawlina & Drake, 2016). According to Bullen et al. (2020), the efficacy of US sessions in teaching and learning anatomy is underpinned by authentic learning theory.

In authentic learning, the real-life setting ought to be incorporated into the teaching session to capture students' interest (Pawlina & Drake, 2016). According to Ganguly and Chan (2008: 56), as anatomy educators, "it becomes indispensable for us to edify the material in a clinical fashion that can help students to encounter anatomy in real life". The emergence of technological devices, such as US, can provide students with a more authentic learning experience based on investigation and hands-on learning (Lombardi, 2007). US technology is also being incorporated more frequently in anatomy research and will be a valuable tool for postgraduate students (Bullen et al., 2020). Partaking in the US sessions shifts learners from passive listeners during didactic teaching sessions to dynamic and actively engaged students who will lead innovation in anatomy research. This will motivate the experience gained from the US sessions to be linked with active cognitive schemas (Khalil et al., 2005; Qiao et al., 2014) that can be effortlessly recalled as needed (Bullen et al., 2020).

Pawlina and Drake (2016) proposed four pillars of authentic learning pedagogy in anatomical education. 1) Teaching resources suited for authentic learning should have notable intrinsic value; 2) authentic learning should offer outstanding instrumental value; 3) authentic learning should enable professional realism, and 4) the information obtained in authentic learning should be transferable and easily applied in other circumstances. Ultrasound has high instrumental value, has real-world application and the knowledge acquired can be transferable to clinical practice as well as postgraduate studies and research.

2.3 CONCLUSION

The purpose of this literature review was to review the existing state of the literature on the use of US to teach and learn anatomy; to find key authors, articles, theories, and findings on the use of US in teaching and learning anatomy; and to identify gaps in knowledge about the use of US in anatomy education. The literature clearly shows evidence of the benefits of ultrasound teaching as well as the fact that anatomy educators can be trained by clinicians to incorporate US during dissection sessions. The value of ultrasound is evident from the literature and will be worth investigating in the undergraduate clinical anatomy setting. Furthermore, although ultrasound training may not always increase students' performance, it may lead to increased interest in learning anatomy for enhanced clinical practice. The following chapter will describe the research methods of this study.

3. RESEARCH METHODS

This chapter discusses the research design that established the basis of the research study. The research methods include an explanation of the study setting, the research population and the selection process used to successfully engage the relevant participants. Furthermore, the data collection and analysis, as well as the ethical considerations and the steps taken to ensure research trustworthiness, will be described.

3.1 RESEARCH DESIGN

A qualitative case study design within an interpretive/constructivist paradigm was followed to explore students' perceptions on the use of US in teaching and learning anatomy. The study was specific to the context of the Faculty of Medicine and Health Sciences (Stellenbosch University), focusing on undergraduate clinical anatomy students. This method was used to explore and produce perceptions that are expected to inform us about educational practice.

3.2 RESEARCH SETTING AND POPULATION

The study occurred at the Division of Clinical Anatomy, Faculty of Medicine and Health Sciences, Stellenbosch University. The study population included all third-year clinical anatomy students (25 students).

3.3 SAMPLING

Sampling is the process used to select a specified number of participants from a population (Botma et al., 2010). The recruitment of the clinical anatomy students in the Division of Clinical Anatomy was conducted in a non-coercive manner. To avoid unnecessary influence, participants were recruited by electronic posting on SUNLearn (by the researcher). The participant information sheet (Appendix A) was emailed to the entire third-year anatomy class after an announcement was posted on SUNLearn (Stellenbosch University's online learning management system). The researcher handled all the notifications and electronic correspondence. A follow-up call was conducted in the same manner.

The sampling approach for the evaluation of the use of US in teaching and learning anatomy was a convenient one, namely all participating clinical anatomy students. The reason for making use of convenience sampling is that it is the least time consuming, allows for ease of sampling, and is the least expensive (Bornstein, Jager & Putnick, 2013). Convenience sampling also ensured inclusivity,

namely that all students in the group were invited and had an opportunity to express their views. To get students of all perceptual capabilities, and not just the students that perceived the US as positive, the invitation was carefully worded to ensure that students were encouraged to give both positive and negative feedback.

The following step was to obtain consent from the respondents who were interested in volunteering for the study. Eleven (11) participants volunteered. The volunteering individuals had a chance to sign the written consent form under the supervision of the researcher (Appendix A). All participants were invited to virtually discuss the study with the researcher to deal with any apprehension. The researcher did not collect data during regular online class meetings and face-to-face practical sessions.

3.4 ULTRASOUND SESSION INSTRUCTIONAL DESIGN

Ultrasound sessions were incorporated during routine dissection/practical sessions of the neck region. The anatomy of the neck and thyroid was used as most anatomical structures can be visualized easily and students can perform the ultrasound on themselves (Swamy & Searle, 2012). The hands-on session objectives were developed in advance in partnership with the anatomy course coordinator and aligned with the outcomes of the anatomy dissection sessions. The US session was implemented together with the corresponding body region (neck) from the lecture material.

The learner-centred, instructional design model for the US session followed the PLHET model of preparation, linking, hooking, engagement, and transfer as described by Jurjus et al. (2014). The PLHET model with each component, purpose, and what was done during the US session can be seen in Table 1.

Table 1 PLHET model (Jurjus et al., 2014)

Session component	**Purpose**	**Ultrasound session**
Preparation	Provide learners with background information and set expectations.	Virtual lectures, videos and outcomes were posted on SUNLearn before the session.
Linkage	Stimulate students' learning: link what is to be learned to what learners already know and/or have experienced.	Reference to the information from the anatomy lecture session.

Hook	Stimulate students by showing the significance of the material to their work.	Clinical scenarios (thyroid biopsy and pathologies) were discussed during the session.
Engagement	Have students apply the material, integrating it with their prior knowledge/skills, and generating new knowledge/skills.	The demonstration was done by the instructor using the ultrasound device.
Transfer	Strengthen retaining of recent learning by way of having students apply it to a new situation.	Students used the ultrasound device themselves and identified the thyroid gland, common carotid artery, and the external jugular vein.

The preparation phase began by delivering theoretical content and setting expectations (Jurjus et al., 2014). The preparation component included videos and learning objectives for the session that was posted on SUNLearn. The participants were informed of the two learning objectives to help them understand what they are to learn during the practical session. This was delivered before the instruction commenced. Two videos were linked on SUNLearn: "The fundamentals of US" (Clarius Mobile Health, 2016) and "How to identify the structures of the neck using US" (Medmastery, 2017). The linkage component helped the participants make sense of the latest information relating to the work that they covered during the lecture session on the anatomy of the neck.

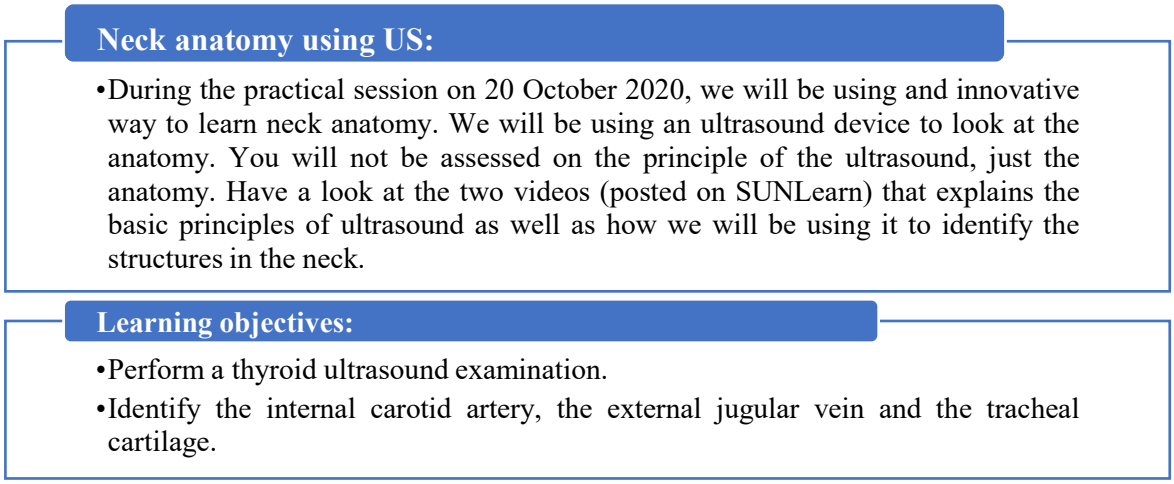

Figure 1 Relevant information and learning objectives posted on the module page on SUNLearn

A demonstration of the US machine (Versana Active) by the lecturer during the practical session formed part of the engagement phase. This was done during a routine practical dissection session of two hours. Initially, the plan was to use the US to scan a cadaver; however, this would have limited the living anatomy component of the session. Thus, a colleague in the Division of Clinical Anatomy volunteered and gave consent to be scanned, as a demonstration to the students. Before accepting the colleague as a volunteer, he was pre-scanned. One of the challenges mentioned in the literature is the possibility of identifying or finding existing pathology, thus pre-scanning is recommended (Allsop et al., 2021).

During the US session, a clinical scenario (thyroid biopsy) was discussed to excite the students (hook phase) by showing the relevance of the sessions to anatomy and the clinical setting. Lastly, giving the participants a chance to use the US device formed part of the transfer phase. The students used the US device to scan themselves as can be seen in Figure 2. Two labelled diagrams, a transverse, and a longitudinal/sagittal section of the neck were placed at the US station (as can be seen in Figure 2). The labelled diagrams included an illustration of the placement of the probe and the subsequently labelled transverse and sagittal images produced by probe placement.

Figure 2 Clinical anatomy students during the US session (Photo taken by the researcher, 20/10/2020)

3.5 DATA COLLECTION AND MANAGEMENT

The research question was aimed at obtaining students' perceptions about their views on the use of US in the teaching of anatomy. To answer the research question, students were invited to participate in virtual focus group interviews on Microsoft Teams™. Microsoft Teams was used as a web conferencing service because SUNLearn supports it, with which participants are already familiar. COVID-19 regulations are currently affecting the way focus groups are conducted, to ensure social distancing, thus a virtual focus group was implemented instead.

Each virtual focus group discussion lasted approximately 60 minutes (Kite & Phongsavan, 2017). Three focus group sessions were conducted. A single focus group consisted of 3-5 students (Breen, 2006). The virtual focus group interview schedule can be seen in Appendix B**.** Ten questions were asked to each group, which guided the interviews. Data recording of the focus groups was done through voice recording on Microsoft Teams. Notes were made immediately after the virtual focus group sessions by the researcher.

Within anatomy education, focus groups and interviews are often employed approaches of data collection as they are suitable approaches for determining perceptions and experiences (Smith, Stabile & Finn, 2018). Focus groups are carefully planned, focused interviews with several participants (4–6 participants), which allow the participants and a facilitator to interact spontaneously with one another and to build on thoughts and dialogue (Breen, 2006; Botma et al., 2010). Focus group interviews semi-structured and guided in questioning, coordinated by the researcher (Smith, Sharp & Dilley, 2019). This method permits the gathering of group-generated data, which can be a demanding experience. However, according to Brandl et al. (2018), an open-ended focus group can deliver rich solution-based responses that makes it a worthwhile tool to use. According to Kite and Phongsavan (2017), the level of discussion and the quality of the data obtained in a virtual focus group is similar to that found in face-to-face focus group discussions.

3.6 DATA ANALYSIS PLAN

The thematic analysis of the data obtained from the focus groups was conducted by using the six steps of Creswell (2014).

Step 1 included to organize and prepare the data for analysis by transcribing notes and audio recordings of virtual focus group interviews. The first stage of thematic analysis includes sorting and preparing data for analysis by transcribing the discussions, reading through the raw data, and organizing data according to its source. In this study, the researcher transcribed all interviews into separate encrypted Microsoft Word documents.

Step 2 included developing an overall sense of the data and reflection on the general meaning (Botma, et al., 2010). This phase required all data to be read and an overall sense of information to be gained. The researcher then reflected on the general meaning by annotating the transcripts and noting general feelings and thoughts.

Step 3 entailed coding the data. Coding refers to the process of organizing data into segments of text before attaching meaning to the information (Botma et al., 2010). Text within the transcripts was highlighted and assigned one or more relevant codes which consist of words or phrases. The codes were developed according to the information brought forward by the participants and were not predetermined. In this study, coding was completed using the free version of QDA (Qualitative Data Analysis) Miner Lite. As previously described, the data was initially coded by the researcher, re-coded, and then the researcher's codes were reviewed by the supervisors.

Step 4 included describing and identifying themes (Creswell, 2014). The themes refer to the key findings and were displayed from multiple perspectives and reinforced by varied quotations and evidence (Botma, et al., 2010). The coding process is used to generate a segmented understanding of the participants' views. Generated from the coding process are several themes, used to group coded information, forming the main findings of the study. Themes represented the perspectives of multiple participants and were supported by quotations from the transcripts. This study identified six main themes. As previously noted, the researcher presented the proposed themes, which were discussed and adapted by the research team.

Step 5 involved presenting the findings. This included a detailed discussion of several themes. The researcher then decided how the findings will be appropriately and effectively represented to the reader. This study displayed findings as narrated passages describing the themes, accompanied by relevant direct quotations from the interview transcripts. Additionally, a tabulated representation of the themes and sub-themes is provided to summarise the findings.

Lastly, step 6 involved interpreting the data. The ultimate step of the thematic data analysis process involved interpreting the data. This involved the interpretation of the information by the researcher with influence from the available literature and theories. The researcher documented the interpretation of the information in the discussion section of this study according to the themes.

3.7 ETHICAL CONSIDERATIONS

This study involved human participants and was approved by the Faculty of Medicine and Health Sciences, Health Research Ethics Committee (Appendix C) and institutional permission was granted

for the study. Volunteering candidates were asked for written consent and all the information was handled confidentially (Appendix A). Participation was voluntary and had no significance (positive or negative) on students' status in the course. To avoid unnecessary influence, participants were recruited by electronic posting on SUNLearn by the researcher. Additionally, the students were supplied with the name and contact information of an unbiased third party (HREC) whom they may contact should they feel coerced at any time throughout the process. All participants were also invited to discuss the study with the researcher to deal with any apprehension. The researcher did not collect data during regular class meetings.

During the virtual focus groups, the identities of the participants were treated confidentially. Participants of the virtual focus group only used initials and were asked not to tell any outsiders what any participant shared in the group. Again, it is not possible to guarantee that the participants will keep the discussions private. The researcher cannot guarantee confidentiality in focus group discussions; however, all participants share the responsibility for confidentiality. This was explained to the participants. The virtual focus groups may entail some loss of confidentiality; however, all identities of participants were kept confidential in the reporting of the research study.

Only the researchers had access to data and digital recordings. All formats of data were stored in a lockable cupboard and electronic data was encrypted and stored in the same lockable cupboard. The researcher disclosed her intention to publish and disseminate the findings before the commencement of the study. Data, both in an uncoded and encoded format (electronic and in document form), will be securely retained for 15 years by the researcher (HREC, 2019).

The researcher was involved in undergraduate anatomy lectures as an educator and is the course coordinator for third-year anatomy courses. The potential advantages of the researcher being an insider conducting the interviews included easier gaining acceptance, trust, and cooperation (Bonner & Tolhurst, 2002). Disadvantages of being an insider included a bias towards interpretation/findings in line with the researcher's own opinions (Bonner & Tolhurst, 2002)

Volunteering participants were not remunerated financially but were offered a gift (a branded anatomy facemask) as a token of appreciation. The gift was not used to coerce the participants. The gift was an expression of gratitude for the participants' time and for sharing their reflections. According to Singer and Couper (2008), there must be a statistically noteworthy interaction between the size of the risk and the size of the incentive if incentives are to be treated improperly influential. In addition, there were no/minimal risks for participants involved in the study.

3.8 QUALITY OF THE DATA

The four criteria to consider guaranteeing rigour in qualitative research are listed as dependability, credibility, confirmability, and transferability (Botma, et al., 2010).

According to Botma et al. (2010), qualitative reliability or dependability shows that the researcher's methodology is consistent. The reliability of this study was confirmed by recording data accurately, systematically scrutinizing transcriptions for correctness, constantly reviewing the data, being flexible and open about progression and thoughts, and crosschecking codes developed by the researcher (Frambach, van der Vleuten & Durning, 2013; Creswell, 2014). Furthermore, the researcher ensured dependability by providing a comprehensive description of the logically executed research methods. Additionally, the dependability was increased by making a clear audit trail of the research process followed available. The auditable trail includes the recorded methods, recorded virtual focus groups, transcripts, and interview schedule.

Credibility or validity relates to the accuracy or dependability of the results (Botma et al., 2010). To guarantee the validity of this study, the researcher provided a rich and detailed description, and the bias of the researcher was clarified by creating an opportunity for self-reflection (Botma et al., 2010; Creswell, 2014). Reflexivity increases the credibility of the research by enhancing more unbiased analyses of data and reporting results (Ramani & Mann, 2016). The benefits of reflexivity further include accountability, dependability, richness, clarity, integrity, support, and personal growth (Probst, 2015). This study also used peer debriefing to ensure credible research. Peer debriefing ensured that the researcher's analysis and interpretation of the interviews were not influenced by personal bias and the participants' views were correctly interpreted. Further internal credibility and validity were guaranteed by a detailed description of the participants' perspectives by transcribing audio recordings verbatim.

Confirmability denotes the objectivity of the research (Frambach, van der Vleuten & Durning, 2013). Peer debriefing, reflexivity, and an audit trail were implemented to ensure confirmability. To enhance the credibility of the study, the researcher maintained a reflective journal after each virtual focus group. The reflective journal allowed the researcher to note their feelings after the virtual focus group and reflect on these emotions before analysing the data to avoid personal bias. Furthermore, the researcher approached each virtual focus group objectively and allowed the participants to give a full answer before commenting, to avoid influencing the responses.

Transferability determines whether the findings can be transferred to an alternative setting. This study is related to a specific group and is not open to generalisation. However, elements of the findings may

be general and related to other groups in medical education (Frambach, van der Vleuten & Durning, 2013).

The final technique to ensure the quality of the research design was to incorporate an inclusive range of different perspectives (Cleland, 2017). In practice, this is ensured through presenting results from various participants. All participants were labelled according to focus group, female, or male (for example, P1MFG1 would be participant 1, male, focus group 1). This demonstrates that the data does not just represent the perception of one or two participants, but that there is some sort of pattern or cohesion to report (Cleland, 2017).

4. RESULTS AND DISCUSSION

In chapter 3, the methodology of the study explained a qualitative method utilizing virtual focus group discussions. The results from the virtual focus group interviews are discussed in this chapter through formulations of themes and sub-themes that were generated as reactions to the research question, inquiring about students' perceptions on the use of US as an add-on to cadaveric dissection. Firstly, the results of the study will be outlined and evidenced with quotations from the virtual focus group interview transcripts. Then the results of each theme will be followed by the discussion of the findings, contrasting, and comparing them to the relevant literature.

4.1 PARTICIPANT IDENTIFIERS

Table 2 supplies a summary of the virtual focus group discussions and the information of the study participants. Three virtual focus group discussions were held over two days after the US session (Appendix B). The focus group consisted of three to five students. Microsoft Teams was used as a web conferencing service. COVID-19 regulations affected the way focus groups were conducted, to ensure social distancing, thus virtual focus groups were implemented instead. Each virtual focus group discussion lasted for about 60 minutes as mentioned in chapter 3. Data recording of the focus groups was done through voice recording and transcribed on Microsoft Teams.

Table 2 Information about the study participants

Participant number (P)	**Focus group (FG) session**	**Male (M) /Female (F)**	**Identifier code**
P1	FG1	Male	P1FG1M
P2	FG1	Female	P2FG1F
P3	FG1	Male	P3FG1M
P4	FG1	Male	P4FG1M
P5	FG1	Male	P5FG1M
P6	FG2	Female	P6FG2F
P7	FG2	Female	P7FG2F
P8	FG2	Female	P8FG2F
P9	FG3	Female	P9FG3F
P10	FG3	Female	P10FG3F
P11	FG3	Female	P11FG3F

4.2 THEMES

Table 3 shows the six main themes and sub-themes generated from the participants' responses. Responses are included in italics as direct quotations to reflect participants' answers. The six main themes are the study of living anatomy, learning cross-sectional anatomy, enhanced relevance of anatomy learning, increased interest in anatomy, instructional design, and the technical and affective experience of using the US.

Table 3 Main themes and sub-themes of study

Themes	Subthemes
1. The study of living anatomy using the US.	○ Comparing using the US to cadaveric dissection ○ Functional/moving anatomy ○ Surface anatomy
2. US and learning cross-sectional anatomy.	○ Dimensional learning and enhanced understanding ○ Textbook ○ Relations between different anatomical structures
3. Enhanced relevance of anatomy learning.	○ Applied anatomy ○ Clinical relevance
4. Increased interest in anatomy after the US sessions.	○ Motivation to learn ○ Memory retention
5. Instructional design of the US session.	○ Labelled US diagrams ○ Pre-ultrasound material ○ Instructional format and group size ○ Time
6. The technical and affective experience of using the US device.	○ Introduction to the US equipment and sonogram interpretation ○ Excitement to use the US device ○ Hands-on experience of using a US device

4.2.1 Theme one: The study of living anatomy using the US

Three sub-themes were identified in the theme of the study of living anatomy. This theme describes students' perceptions of US as an imaging instrument to enhance their learning of living anatomy. The sub-themes are named as: comparing using US to cadaveric dissection, functional/moving anatomy, and surface anatomy.

Comparing using the US to cadaveric dissection

Most of the participants in all the focus groups compared using the US to study living anatomy with the dissection of a cadaver. Students in the clinical anatomy undergraduate programme mostly use cadaveric dissections and the use of prosections (previously dissected specimens) to aid them in their anatomy learning. The dissection practical session takes hours, as students need to remove all the layers of skin, fascia, and/or muscle before seeing deeper structures. The participants thus felt that the US was a less time-consuming and less tedious way to study anatomy-compared to the cadaveric dissection.

> *Whereas with ultrasound, it's a very quick process. Where it's not as easy on a cadaveric specimen.* P8FG2F

Furthermore, the cross-sectional view without dissection was valued as seen in the following quote.

> *Especially, it was very interesting to know that although you're not actually cutting the body, you can still like get a transverse section and a longitudinal section. So, that was very interesting.* P4FG1M

The participants also commented on the real-time application of US in teaching and learning anatomy. Real-time US refers to seeing multiple images of anatomical structures in motion (also discussed more in the following sub-theme). Some participants mentioned that with US you can see the structures in real-time, in a non-invasive manner and without dissecting anything. In practical sessions, students are used to having to dissect a cadaver to study the deeper anatomy and they appreciated the fact that they did not have to dissect a body to see the anatomy.

> *Or you always think you must cut a specimen, so you'll need a donor body to do it. But now with an ultrasound you can view it in real-time.* P4FG1M

> *We often joke that we would love to see what our anatomy looks like on the inside, so I think it's also cool because the ultrasound is a way, we can do that in real-time without cutting ourselves open.* P8FG2F

However, many of the participants felt that they prefer the US being combined with cadaveric dissection, rather than just using the US alone to study anatomy. Participants felt that they valued studying the cadaveric specimens before using the US and being able to compare the diverse ways of studying anatomy by using US and through dissection. The cadaveric dissections added meaning to and enhanced their understanding of the images seen with the US.

> *But it was nice to also look at all the structures in the cadavers first before the time and then compare that to living people as well.* P2FG1F

> *I think if you have a dissection before the ultrasound and then look at the ultrasound structures and then maybe go back to dissection afterwards just to look at it again from the outside and see again this is what the structure looks like in a different view.* P7FG2F

The US intervention allowed the students to view anatomy in a short space of time, without having to dissect a cadaver. Although the participants appreciated this fact, they still preferred studying anatomy in a multi-modular way by combining US with cadaveric dissection. The finding also highlights the capability for US to improve anatomy education when the US training is offered after the applicable gross anatomy content.

Functional/moving anatomy

Functional anatomy refers to the study of anatomy in relation to function. Many of the participants found it positive that they were able to see the functional anatomy in a living person. Participants felt that using the US helped them to bring anatomy and other basic sciences to life.

> *So, because we do Physiology and Anatomy throughout, I think being able to see the function and how it relates to Anatomy in real-time helps a lot not only with our study of anatomy but also our understanding of Physiology. So, I definitely think it's beneficial.* P8FG2F

> *Living anatomy is so interesting because it's dynamic and you can see exactly what's going on (using the US) and how things are moving and working.* P11FG3F

Participants also commented on being able to see the common carotid artery throbbing and the fact that the jugular vein constricts if you apply pressure to the neck area. In addition, the students found that visualising the larynx moving when the person spoke was fascinating.

> *I definitely think that being able to see, for example, the artery pulsating, or you are being able to collapse a vein. It might not be so much an educational thing, but I think it definitely is an interesting little add-on that we got to see, and I really appreciated that.* P3FG1M

> *And then also when we looked at the voice box and how you would see it moving, I found that very interesting, but also, easy to identify.* P9FG3F

Participants perceived that studying living anatomy using US adds a dynamic element to the study of anatomy that the cadaver cannot achieve, i.e., visualizing how structures (the larynx) move in a living person during speaking and how blood flows through an artery

Surface anatomy

Surface anatomy is the study of the exterior features of the body, specifically in relation to its interior parts. A few participants commented on how using the US added to their understanding of the visual surface anatomy and linking it to the deeper anatomy.

> *It's easier to connect the surface anatomy that we learn about with what's actually going on inside. Because if you dissect a cadaver, you either look at the surface anatomy or the inside. While studying the ultrasound on a living person, you connect it a lot easier, which makes it a lot easier to study anatomy and connect the difference aspects of anatomy*. P7FG2F

> *You learn to look for landmarks and you can link the surface anatomy of the neck to the internal structures as well.* P7FG2F

The study of living anatomy using the US assisted the participants in learning structure, function, and surface anatomy. Live US adds value by displaying the action of anatomical structures and the dynamic state of human anatomy, elements that might not be experienced in the traditional setting of the dissection hall with cadaveric specimens.

Discussion of theme one: The study of living anatomy using the US

Living anatomy, defined as the anatomy of living humans, is gathering importance in contemporary anatomical science education (Ganguly & Chan, 2008). Cadaveric dissection teaches the hand and eye, but then again, it does not show in what way human anatomy functions. To think of anatomical structures in terms of function, students must relate the cadaveric structures with the information they might find from the system and the function of these structures in the living body. Therefore, the dynamic nature of US allows the demonstration of movement and integration of structures within a living body, with visualisation of the functional anatomy – for example, the arteries throbbing and the moving of the vocal cords when a person speaks.

Traditionally, cadaveric dissection is the preferred pedagogical approach for teaching and learning anatomy (Turney, 2007; Ganguly & Chan, 2008; Bergman, 2015). Dissection dates back as early as anatomy itself and has stood through time as one of the most vital parts of early medical education. Although dissection is perceived as the gold standard to teach and learn anatomy, research has also suggested that cadaveric dissection is not a standardized learning event (Winkelmann, Hendrix & Kiessling, 2007; van Wyk & Rennie, 2015). Dissection can be perceived by a small group of students as a poor learning strategy since students become emotionally afflicted and cannot engage in the activity (Flack & Nicholson, 2018). In the study by van Wyk and Rennie (2015) the participants

revealed positive experiences in learning anatomy through dissection, however, a small group perceived dissection as ineffectual to their learning. They viewed dissection as time-consuming, perceived cadavers differ too much from living people and requested additional resources to aid in their understanding.

Similarly, in this study, students appreciated the multimodal teaching approach by incorporating different elements in their learning, such as complementing the dissection session, traditional atlas, and didactic lectures with the use of US. Bullen et al. (2020) found that the multimodal learning approach, the add-on of the US sessions to the anatomy module, which included didactic lecture and practical sessions, support groups of students with different preferences. Moxham and Moxham (2007) described that using cadaveric dissection and medical imaging together advances students' capability to recognize anatomical structures and offers long-term memory retention.

This study further confirms that studying living anatomy using US enhances understanding of how anatomical structures in living humans' function and move in relation to one another in a way that cadaveric dissection cannot. The participants' feedback that the US added value to better learning of living anatomy, is supported by evidence in the literature (Ivanusic, Cowie & Barrington, 2010; Stringer, Duncan & Samalia, 2012; Patten, 2015; Allsop et al., 2021). As a non-invasive and non-destructive way to see inside the living body, US is a perfect add-on to teach living anatomy (Royer & Buenting Gritton, 2020). However, many anatomical structures with intricate courses and relations are challenging to observe with US; dissection, although perceived as time-consuming, provides a haptic approach that cannot be achieved by ultrasound. Dissection continues to be invaluable to identify complex anatomical structures, such as nerves and enables 3D perspective and tactile perception (Hammoudi et al., 2013).

Surface anatomy and living anatomy are vital for "understanding the foundation of physical examination, and the interpretation of clinical findings" according to Azer (2013: 416). Students found the US session helped their understanding of surface anatomy and this is echoed in similar studies in the literature (Smith, Sharp & Dilley, 2019; Bullen et al., 2020) and it provided a clear view connecting surface anatomy with internal anatomy (Jurjus et al., 2014). Although, not much emphasis is placed on teaching surface living anatomy in textbooks according to Azer (2013), however, US included in anatomy practical sessions might change this in the future.

4.2.2 Theme two: US and learning cross-sectional anatomy

Cross-sections are two-dimensional views of gross anatomical structures in the transverse planes. Alongside the arrival of modern-day medical imaging, additional anatomical cross-sectional images

are available as learning resources for students. Thus, a solid understanding of the spatial relationship of anatomical structures is essential in anatomy learning. This theme includes all the comments on how the US practical session added to their learning of cross-sectional anatomy. Three sub-themes were identified in this theme namely, dimensional learning and enhanced understanding, textbook and relationship between anatomical structures.

Dimensional learning and enhanced understanding

All the comments on how the US added a different dimension or perspective to learning anatomy are included in this category. Undergraduates frequently experience difficulties in their spatial understanding of 3D anatomy from 2D images, for example, images found in anatomy textbooks and on the internet. Some of the participants commented on the value added to observing anatomy in a different dimension and seeing it from a new perspective.

> *But also, it adds that other dimension to your learning.* P4FG1M

> *Improving our understanding of it [cross-sections] and seeing it from a different perspective.* P6FG2F

> *It really does help to put things into perspective in terms of visualizing it almost in 3D.* P11FG3F

A participant also felt that the US helped them see the various layers of skin, tissue, muscle, and it helped them visualize a different dimension compared to cadaveric specimens where the layers were removed.

> *I think when we do cross-sectional anatomy with the cadaveric specimens; we often only look at one cross-section in isolation. We never look at the layers.* P8FG2F

Most respondents found the US device a valuable aid to improving their understanding of three-dimensional anatomy.

Textbook

This category includes positive and negative comments on whether the US helped with cross-sectional understanding when compared to a picture in a textbook. Textbook diagrams can be hard to interpret as pictures are just a single view of complex anatomical structures, consequently, how the structures positionally relate to each other can be difficult to visualize from a simple textbook

diagram. Thus, some participants perceived the cross-sectional view of the US to be more realistic than just looking at a static image.

> *I think that it helped me visualize the structures in relation to one another, especially in the cross-section. I think it's quite difficult to see how things lie in relation when you're just looking at a picture.* P10FG3F

> *I think it always helps students, especially like myself, to view it in real life and to see a real-life application because you get tired of just seeing the cross-sectional views in a textbook.* P4FG1M

Participants also commented on how they were surprised that the cross-sectional view in the textbook depicted structures in a manner that were less distinguishable than with the US in real-time.

> *Think a lot of textbooks tend to make structures look similar when they illustrate how things look. For example, the artery and the vein like we saw yesterday. They tend to make them look very similar, whereas yesterday in the ultrasound I was surprised to see that they do look very different.* P5FG1M

However, some participants felt that the cross-sectional view of the US image was valuable but was just a duplication of the images in the textbook.

> *I think it did add a certain amount of value, but also, at the same time, it was sort of a replication of the textbook. The cross-section in the textbook was like what was seen in the ultrasound.* P3FG1M

The participants perceived the US image to be more realistic than that of the static image in the textbook. Static depictions from textbooks were most likely to make more sense to students having viewed the same cross-sectional image from the US.

Relations between anatomical structures

This category includes all the comments on how the US added to learning structures' relationship to other anatomical structures in a cross-sectional view. As anatomy is the study of the structure and relationship between anatomical structures, learners need to study how anatomical structures relate to one another. Participants felt that the US assisted them with visualizing the anatomical structures in a cross-section more clearly.

> *So, you can see how structures relate to each other while they're still together in the system.* P1FG1M

> *I think that it helped me visualize the structures in relation to one another, especially in the cross-section.* P10FG3F

Participants also commented on how the cross-sectional view will aid them with learning recall as well as the value it has when it comes to identifying anatomical structures in spot tests.

> *It's nice to be able to see all the spatial relations and that also just helps with learning and remembering, especially in anatomy.* P9FG3F

> *Definitely added a lot of value and will help with understanding relations and help with understanding exactly what you are learning.* P11FG3F

> *I think that the cross-sectional view helps a lot with getting the relations between the midline and what lies laterally. I think that's very important, especially for a spot test.* P3FG1M

It is clear from the participants' feedback that the US delivers a reliable approach for helping them understand the spatial relations between anatomical structures, and with recall/long term memory, and potentially performing better in assessments.

Discussion of theme two: US and learning cross-sectional anatomy

As mentioned previously, cross-sections are two-dimensional views of gross anatomical structures in the transverse planes. Gross anatomy serves to orientate students to the complex 3D nature and relationship of the structures within the human body. In this study, the participants perceived an improvement of 3D anatomical imagination. The ability to have a clear understanding of the spatial relationship of anatomical structures is an essential skill in anatomy learning (Vorstenbosch et al., 2013). According to Vorstenbosch et al. (2013), a good spatial ability is advantageous for learning anatomy and may be useful for students' spatial comprehension.

Including innovative technologies as an add-on to dissection enables observing the system in vivo and advances students' awareness of spatial relationships and the relationship between anatomical structures (Estai & Bunt, 2016; Alexander et al., 2021). Comparable with literature, participants found that using the US had improved their understanding of spatial relationships of key anatomical structures (Moscova et al., 2015; Estai & Bunt, 2016). Furthermore, participants compared the cross-sectional US images with anatomical cadaver cross-sections and textbook depictions and found it had been valuable in adding to their comprehension.

Even though this study only used 2D US, the participants viewed the combination of the 2D images on the living subjects and cadaver dissections (3D) as valuable. In the study by Carter et al. (2017),

as discussed in the literature review, they found that 3D/4D US may foster and further reinforce spatial relationships of the thyroid gland taught during anatomy dissection. However, the participants found that the combination of the 2D US with the 3D cadaveric dissection enhanced their understanding of three-dimensional anatomy. Studies have also shown that anatomy dissection improves the visual-spatial abilities of medical students (Bogomolova et al., 2020). Thus, further motivating combining cadaveric dissection with US in order to augment spatial ability. Nevertheless, in future, it might be meaningful to incorporate 3D/4D probes as a supplementary learning tool to anatomical dissection sessions.

Participants also perceived the cross-sectional view of the US to be more realistic than just looking at a static image. In the clinical setting, the goal is to generate an image that is as realistic as possible. Anatomy textbooks and atlases show a different reality compared with viewing anatomy structures in real-time with US (Rodríguez-López et al., 2020). Furthermore, US permits the visualization of anatomical structures and relationships; anatomical structures which are otherwise difficult to observe using static models or images (Royer & Buenting Gritton, 2020).

4.2.3 Theme three: Enhanced relevance of anatomy learning

This theme includes all the responses on whether ultrasound integrated undergraduate anatomy with clinical practice, postgraduate studies or applied to other aspects of anatomy. The two categories in this theme are applied anatomy and clinical relevance. Depending on the future intentions or personal aspirations of students, they were inclined to describe applying anatomy to different modules, to postgraduate studies or commenting on how the US highlighted the clinical relevance of anatomy.

Applied Anatomy

This category includes all the comments on the participants' perceptions of whether the US session aided them to apply their learning of anatomy to other aspects. Participants felt that they could apply this new knowledge to other courses as well. In another anatomy module, (ANA364) students were tasked to develop a research proposal and the US session had prompted innovative ways to develop their research proposals as well.

> *The US practical session really made me curious to see how I can apply this in my studies [research proposal]. For example, I'm busy with the research proposal and I thought 1) how can I implement this or 2) how can I look at the structures that I'm studying a little bit better 3) can I use this to improve my study?* P7FG2F

> *I was also thinking about my anatomy proposal and trying to find things that I'm trying to look for more in my proposal with the ultrasound, and I think I was just more adventurous in trying to find new things that maybe I wouldn't have been [able to find] in a cadaver just because I wasn't sure where to look.* P8FG2F

Participants also noticed that the US links undergraduate anatomy with postgraduate anatomy. During Honour's degree in Clinical Anatomy at Stellenbosch University, students can enrol in an elective known as Clinical and Surgical Anatomy. Participants felt that the US session made them excited and linked their undergraduate with what they might do during postgraduate studies.

> *Also, to connect your undergraduate [anatomy] to your postgraduate [anatomy] to see it clinically and to apply your knowledge in a sense.* P6FG2F

> *Because if we decide now to do postgrad, things like clinical and surgical anatomy which does influence lives but not necessarily directly at the time. So, I think it was very important for us to see that it is important that we know it because this [postgraduate anatomy] is why.* P8FG2F

Undergraduate third-year clinical anatomy students mostly apply for medical or allied health degrees after completion of their degree and/or pursue an Honour's degree in Clinical Anatomy or other related fields. Participants, therefore, mentioned how the session made them more eager and interested to pursue Honours in anatomy the following year and valued the benefits of it in their future careers.

> *When I was deciding what Honours programme I wanted to do, what really sold me was all the practical aspects you get exposed to in postgraduate studies in [Division of] Clinical Anatomy. Being able to do the ultrasound and use this equipment.* P10FG3F

> *I think it's just going to make them more enthusiastic about learning anatomy and about wanting to take it further.* P11FG3F

A participant, however, mentioned that they felt that the US is not relevant to all facets of the BSc Anatomy course.

> *I think, as mentioned earlier, it will be beneficial, but for certain aspects. I don't think every aspect of our, especially pertaining to our course work, needs ultrasound. But yes, I do think it can benefit some aspects of the course.* P1FG1M

Although implementing US in students' anatomy learning might not be beneficial to all the elements of a BSc (non-medical graduate) degree, participants did agree that they could integrate using the US in learning anatomy with other research modules as well as link it to postgraduate studies in anatomy.

Clinical relevance

This category includes all the comments on how the US highlighted the clinical relevance of anatomy. During the US session, a clinical scenario, thyroid biopsy, was discussed by the facilitator to excite the students (Table 1) by showing the relevance of the US anatomy to the clinical setting. Although the participants are BSc students, they perceived the value of the US session in bridging the gap between the basic sciences and the clinical significance of learning anatomy. As mentioned previously, most undergraduate clinical anatomy students apply for medical and other allied health degrees after completion of their degrees; other students continue to pursue Honour's degrees in anatomy, physiology, medical physiology, or other related postgraduate degrees. The participants perceived that the US session facilitated them to realize why anatomy is important for clinical practice; it highlighted the important clinical relevance of anatomy in medical education.

> *Ultrasound is that perfect link between the two; connecting the textbook notes to what you actually see in the clinical field. And I think definitely this is something that all medical professionals (whether you study Anatomy or medicine or anything like that) will benefit from using to connect the textbook to the actual clinical practice.* P7FG2F

> *We might never have been exposed to an ultrasound if it wasn't for this session, and I don't think I ever understood the importance of knowing the anatomical structures and what that played in things like a nerve block or putting in a central line.* P8FG2F

A participant suggested that a clinician should be brought in to make the session more clinically relevant.

> *I think bringing in a clinician would definitely increase the interest that students feel…* P3FG1M

The US session connected the importance of anatomy to the clinical field. Furthermore, the participants also applied the new knowledge to different modules, research projects, and postgraduate studies.

Discussion of theme three: Enhanced relevance of anatomy learning

One of the great concerns for medical and other health sciences students is connecting theoretical subjects with practical ones and their utilization in clinical practice. Many medical schools have experienced a need for transformation in instructional methods, because of the high content volume, and because the basic sciences often seem disconnected from clinical practice (Heilo, et al., 1997). However, from the feedback received, the US session connected the importance of anatomy to the clinical field (Teichgräber et al., 1996; Dreher, Dephilip & Bahner, 2014).

During health professions education, inadequate integration of foundational sciences, such as anatomy with the clinical realm, may undermine the significance of these subjects. As previously described in section 2.1.4, Stringer et al. (2012) found that using US as a method of teaching anatomy, provides learners with an overview of the clinical value of US, and, by concentrating on anatomical outcomes rather than the acquisition of practical imaging skills, and strengthens the learning of clinical anatomy. Similarly, the present study found that integration of anatomical knowledge with clinical examination and US training might give the students an improved comprehension of anatomy and an invaluable understanding and skills of US, skills that may be advantageous in future clinical practice.

The integration of clinical anatomy into traditional anatomy courses aids the understanding of anatomy and improves clinical thinking (Dettmer et al., 2010). Additionally, the participants also applied their newly acquired knowledge of clinical anatomy and US training to several aspects about other modules and postgraduate studies. Thus, these interactive sessions could stimulate critical thinking skills in undergraduates (Bullen et al., 2020) and play a valuable role in the integration of foundational sciences.

A participant also proposed that a clinician should be brought in to increase the clinical relevance of the session, and this might be an incentive to learn anatomy. A study by Jurjus et al. (2014) found that anatomists could teach living anatomy using US, after basic US training. During the session, the participants felt that the researcher's (an antomist) in-person demonstration (as seen in theme 5) was more useful than the online videos, showing that anatomists with basic training can present the sessions. Nevertheless, in future, it might be valuable to add clinicians to further increase the interest and clinical relevance of the session.

The current study focused on undergraduate clinical anatomy students' perceptions. Many studies found in the literature focus on implementing US in the curriculum of UG medical students as seen in section 2.1 (Heilo et al., 1997; Brown et al., 2012; Hammoudi et al., 2013; Patten, 2015; Allsop et al., 2021). However, there is little literature to support including US for basic science education

students in non-medical degrees (Royer, 2016; Royer, Kessler & Stowell, 2017; Bullen et al., 2020; Alexander et al., 2021). Yet, two recent studies investigated the utility of US as an anatomical learning tool for Bachelor of science students or non-medical graduate students (Bullen et al., 2020; Alexander et al., 2021). Encouraging non-medical students to become skilled in the pedagogic use of US technology will grow an innovative group of anatomy educators eager to implement US sessions to complement anatomy modules at universities (Bullen, et al., 2020). Furthermore, US experience will make clinical anatomy graduates more competitive in the employment market and will be a valuable skill for individuals who intend to teach in a medical school (Royer, 2016).

4.2.4 Theme four: Increased interest in anatomy after the US sessions

Two sub-themes were found in the theme of increased interest in anatomy; motivation to learn, and memory retention. Participants perceived US as a tool that benefits their anatomy learning. Although they were unsure if the US session would increase their test scores in anatomy, they felt that they were more interested and motivated to learn anatomy; it was easier to learn, easier to remember and made them curious about the possibility of pursuing anatomy further.

Motivation to learn

This category includes all the comments on how the participants felt that after the US session, they were motivated to go and look at their notes and textbooks and to learn anatomical theory. The participants perceived that US was a way to improve their motivation to learn anatomy and more motivated to improve their knowledge.

> *It was very new but with that excitement and like that newness also comes a very large interest aspect. So, I feel like I was more interested in learning about that area and going back to my textbook.* P4FG1M

> *It made me very excited to go home afterwards, look at my anatomy notes and study the head and neck section. It made me curious to grow my understanding, even if it's not directly applicable, it made me curious and want to study.* P7FG2F

> *It was easier to study afterwards, now that I had seen it and it was easier to go back to the textbook and study it.* P6FG2F

A participant also suggested that a clinician should be brought in (as seen in theme 3) and added that it might be an incentive to learn anatomy.

> *I think bringing in a clinician would definitely increase the interest that students feel. I think being interested it motivates you to learn and it motivates you to do better.* P3FG1M

US activities promoted students' motivation to learn anatomy because more clinically relevant teaching motivates the students to reinforce their anatomical knowledge.

Memory retention

One of the challenges encountered by many lecturers, including those that teach anatomy modules, is how to assist students to learn and then recall a large volume of facts. Consequently, some participants commented that it was easier to learn anatomy following the US session and they felt that they remembered the anatomical structures better.

> *It was easier to study afterwards, now that I had seen it and it was easier to go back to the textbook and study it. Then I found that my memory retention was greater because I saw it like that.* P6FG2F

> *So, I think that the enthusiasm that came through from using the ultrasound and being able to physically see the structures definitely made it easier to study the work from the textbook after it.* P7FG2F

> *It makes learning easier. I can still remember the muscle that lies in front of it or the orientation of which one's more medial, things like that.* P3FG1M

> *I still can remember the relations that we spoke about in the practical, but it's only been a day, but I feel like I could still take that knowledge or that experience on later throughout the year.* P4FG1M

Some participants perceived the value of the multimodal session to be of great benefit for their memory retention.

> *So, adding different things to your study methods, so the cadaver with images with ultrasound, gives you all the different views of something and for me, it will help me remember things in the long run.* P10FG3F

Some participants felt that it strengthened their anatomical knowledge; however, because they only spent two hours with the US, they were unconvinced of the long-term value.

> *But we also spent quite a short time with it, so it's very difficult to gauge if there was really significant benefit. So, with the limited time we had with it, yes it did benefit, but uncertain about slightly longer-term benefit.* P1FG1M

The US sessions assisted with spatial cognizance, leading to improved student engagement, understanding, and retention of anatomical concepts. This theme was based on whether the participants felt that US added value to their learning of anatomy. Although they felt that they were unsure as to whether it might be directly beneficial to learning anatomy, they did perceive that the excitement of using the US device increased their motivation to learn anatomy, their memory retention of anatomical relationships as well as an increased interest in pursuing a postgraduate degree in anatomy.

Discussion of theme four: Increased interest in anatomy after the US sessions

The results of this study give insight into the question as to whether teaching with innovative modalities, such as US, promotes and enhances interest in anatomy as a subject. The evidence from the present study, as in other studies (Dreher, Dephilip & Bahner, 2014; Royer, Kessler & Stowell, 2017; Rodríguez-López et al., 2020), suggests that the participants had an increased interest and motivation to learn anatomy. According to Rodríguez-López et al., (2020), students who used imaging techniques (such as US) to learn anatomy, developed a long-term positive perception of the subject. A study by Moscova et al. (2015) found that by incorporating imaging in practical sessions, student attendance increased for practical sessions; many students displayed interest in imaging technologies and were motivated to learn more.

This study suggests that hands-on teaching in US promoted meaningful learning and had a positive impact on the memory retention of anatomical information; similar to a study conducted by Dreher, Dephilip, and Bahner (2014). According to Grant and May (2015), the real world, hands-on nature of US assists students to acquire factual learning in a unique way and this can motivate the development of episodic memory. Episodic memory, a category of long-term memory, is linked more closely to experiences and specific events, than to factual learning (Grant & May, 2015). Learning strategies are vital to learning acquisition and memory retentions, for example increasing time spent on activities, creating opportunities for constructive learning, including chances for collaboration between students in groups (collaborative learning) and contextual (Bergman, 2015).

On the other hand, a participant mentioned that because of the brief time spent with the US device, the participant was uncertain of the long-term benefit. A study by Hammoudia et al. (2013), sought students' and teachers' opinions on US-based teaching of cardiac anatomy. Increased motivation to

study cardiac anatomy and physiology was emphasized by 83% of students, however, the educators were uncertain about the long-term pedagogic advantages of a single US session. The participants perceived that the US improved their engagement, understanding, and retention of gross anatomy concepts, even though they only spent one session using this as an educational tool.

4.2.5 Theme five: Instructional design of the US session

The instructional design of the US session (as described in section 3.4) refers to all the elements of the learning materials that were made available to the students before and during the US session. Before the US session, the introduction to basic ultrasound physics and knobology were uploaded to SUNLearn. Knobology refers to the manipulation of US knobs and system controls to get the best image possible from diagnostic US (Dietrich et al., 2019). In addition, at the US station, labelled sonograms of the neck region were placed to help the students with the identification of the anatomical structures. A demonstration was given in small groups and later students were encouraged to use the US themselves. Connecting the US session to the relevant lecture material and motivating students to be active participants in their learning using the US themselves, made the session more purposeful to the students. The categories in this theme include pre-ultrasound material, labelled US diagrams, and instructional format.

Pre-ultrasound material

This category includes the participants' feedback about all the positive and negative aspects of the pre-ultrasound material (two videos and learning outcomes) that were posted prior to the session on SUNLearn. The participants had mixed opinions on the material that was posted on SUNLearn. Some participants felt that the videos were informative, as can be seen from the following quotes.

> *It was very useful. The video that was actually speaking about how to do the ultrasound was very useful and very informative. And the other video where it implemented the physics side of things; was nice to have that kind of background.* P11FG3F

> *I thought it was very helpful. It did help.* P6FG2F

> *I really enjoyed the video. Also, more of for interest's sake, not really to help with the anatomy part of it, but I really liked to understand why we see the image that we see and how the ultrasound machine gives you that specific image.* P10FG3F

Other participants felt that the explanation the researcher gave prior to commencing the US session was more helpful than the online videos.

> *In the videos that wasn't quite very clear. I think the presentation just before we use the ultrasound was a lot clearer. I think you can give the videos over SUNLearn just so that they understand the physics behind it.* P7FG2F

> *The explanation we got at the actual ultrasound session was very helpful in understanding the actual protocol behind performing the ultrasound.* P8FG2F

Some participants did not watch the pre-ultrasound material and felt that the videos would have been more beneficial if they were shown in the practical session rather than online.

> *I think it should have been played before we did the ultrasound [in class] just to get everyone on the same page because we might not have looked at the videos beforehand. Especially everything being online [due to pandemic] we're not very keen to always look at videos on SUNLearn.* P4FG1M

The pre-ultrasound material was seen as interesting and helped the students in their understanding of the basics of ultrasonography; however, others felt that it should have been played before the session in the dissection hall.

Labelled US diagrams

Two labelled diagrams were placed at the US station depicting a longitudinal and transverse image of the neck area as well as probe placement to obtain specific US images (Figure 2). As this was the first time the students used a US machine, they found the images useful. Some participants believed the diagrams assisted them to identify the anatomical structures.

> *I think that because there were reference pictures on the wall, it made it a lot easier because it was labelled on the picture, and we were seeing the image in front of us while we were doing the ultrasound.* P10FG3F

> *I also think that we had labelled ultrasounds right above where we were performing the ultrasound and I think that also helped a lot because we weren't sure what things were supposed to look like in the different tissue types look like on an ultrasound. So, I think having the labelled ultrasound picture also helped a lot.* P8FG2F

> *Having the pictures on the wall was very helpful.* P9FG3F

Participants viewed the labelled US diagrams as effective in aiding them in identifying the anatomical structures. Thus, the use of cross-sectional images, together with line drawings, can support sonogram orientation of anatomical structures during US sessions.

Instructional format and group size

This category includes all the comments about the design of the US session practical session. Participants made suggestions on how to improve the practical session and recommended it should be outcomes-based, with smaller groups and more time should be allocated to it in future. Although learning objectives were posted on SUNLearn prior to the session, participants felt that it should be made explicit during the practical session as to what is expected of them.

> *Just be a little bit more objective-oriented.* P3FG1M

> *A more structured approach to the practical or to the session.* P4FG1M

The class consisted of 25 students, and students were encouraged to form groups of six to observe the demonstration of the device as well as use it themselves. Some participants commented on the group size and that the sessions should be focused on smaller groups and if possible, get wireless transducers that can be shown on bigger screens. Participants felt that there were challenges associated with having only one device shared among six students.

> *When everyone was looking at the ultrasound and standing around the table, then it's difficult to see the pictures [US image] sometimes, so just smaller groups.* P2FG1F

> *It does become a bit crowded and then you tend to lose interest once that happens.* P5FG1M

Participants also commented on the short amount of time they spent with US as well as recommending that more time is spent on the US during practical/dissection sessions of other systems such as musculoskeletal.

> *I think that will really really help as well if we use it more frequently.* P7FG2F

> *I think it would be nice to see things [anatomy systems] through ultrasound like when we are doing musculoskeletal as well, just to see where the muscles lie in relation to one another.* P11FG3F

Participants commented positively on the size of the device (included in theme 6) and the portability of the apparatus but negatively regarding the group size at the US station; they suggested overcoming this by projecting US images onto a large screen. Participants also valued the opportunity to experience an imaging skill they would use in their future occupations and appealed for more practical sessions with the US.

Discussion of theme five: Instructional design of the US session

The learner-centred, instructional design model for the US sessions followed the PLHET mode (as discussed in 3.4) of preparation, linking, hooking, engagement, and transfer (Jurjus, et al., 2014). This approach was based on similar sessions for undergraduate medical students. The US sessions were adjusted for clinical anatomy students, however many aspects of the instructional design that were successful for medical students were also effective for clinical anatomy students. Bullen et al. (2020) used this design to include US to complement anatomy instruction in a non-medical course and participants found the sessions to be arranged efficiently, in a way that strengthened the course material.

The placement of supplemental online learning materials about the US before the session was aimed at improving the students' preparation for the sessions (Allsop, et al., 2020). However, some students noted that they did not study the online material and would have preferred the videos to have been played in the practical session immediately before the US session. To maximize the learning potential of the US session, the students need to be prepared with the relevant information and basic understanding of knobology relating to US.

In addition, students must be aware of the intended learning outcomes of the US session (Patten et al., 2010). The objective was to demonstrate living anatomy and enable students to develop skills in interpreting 2D sonograms of anatomical structures; it was not to instruct students in the use of US apparatus. Although learning objectives (see Figure 1) and pre-ultrasound videos were posted on SUNLearn prior to the session, participants felt that it should be made explicit during the practical session as to what is expected of them. Students wanted more didactic teaching, rather than having to view the pre-ultrasound material online, and a less self-directed and more objective-based approach in the practical session. Reasons for this might be that the students were fatigued from the emergency remote learning that was implemented in March 2020 due to Covid-19 restrictions and/or the fact that the students were not assessed on the US sessions, since many students are motivated by grades. All the students were final-year clinical anatomy students, who were expected to be more independent in their approach to learning; Moscova et al. (2015) had a similar experience with postgraduate students.

Furthermore, participants viewed the labelled US diagrams at the US as effective in aiding them in identifying the anatomical structures. Similarly, findings by Moscova et al. (2015), participants indicated more assistance was required in interpreting US images and participants suggested additional notes with labelled structures. Participants initially found the sonograms difficult to interpret, as seen in theme 6, but found the labelled diagrams assisted them. Thus, the use of cross-sectional anatomy images and line diagrams together could aid in identifying structures during US sessions, similar to findings by Swamy and Searle (2012).

Feedback revealed that the participants would like more sessions and more time per session which is mirrored in the literature (Allsop, et al., 2020; Bullen, et al., 2020; Mumtaz, et al., 2016). Likewise, a study by Bullen et al. (2020) found that students sought additional and longer sessions with the US with smaller group sizes. The student to demonstrator ratio should be kept small to motivate active participation and learning for all students (Bullen, et al., 2020). Learning in a small group setting enriches the learning and understanding of the subject (Ganguly, 2010). Royer and Buenting Gritton (2020) recommended that groups should consist of five (or fewer) students per US device, to allow all participants to observe the probe placement and on-screen images simultaneously. Furthermore, for future sessions, careful thought should be provided to the scheduling and frequency of US sessions, to make sure that it strengthens the overall educational objective of the module.

4.2.6 Theme six: The technical and affective experience of using the US

This theme includes all the comments on the participants' experience of using the US during practical sessions. The subthemes include the introduction to US equipment, sonogram interpretation, the excitement of using the device, and their hands-on experiences of using it. The participants were introduced to the US equipment for the first time during the practical session and were excited to use the US device to learn anatomy. The sonogram interpretation was difficult initially, but participants found that it became easier with practice. Many of the participants were enthusiastic about the opportunity to use the equipment themselves, even though they were uncertain in the beginning.

Introduction to the US equipment and sonogram interpretation

The participants felt that it was initially confusing to use the US; however, as soon as they mastered it, they felt that it was easier to use the device.

> *So initially, it was a bit confusing, but once I got the hang of exactly how we are looking at it and how the images are being made, then it became a lot easier to see what is going on.* P5FG1M

> *Originally, it was quite difficult to orientate yourself and to understand if you place the transmitter like this, it gives you this image and if you turn it around the other way, gives you another image.* P7FG2F

> *I saw people like, really that never used it before they caught onto it very quickly, so it wasn't something that took them a lot of time to adjust to.* P1FG1M

> *It just took some time to get used to how the whole thing looks. But once we got used to it, then it was easier.* P2FG1F

Participants also mentioned that they were uncertain at the beginning of the session, as they had no experience of using a US device, neither interpreting sonograms.

> *At the beginning of the session, it was as if everyone was kind of too scared to use ultrasound and it was kind of like: Are we going to break it and this and that.* P2FG1F

> *I think what made it difficult at first because you look at an ultrasound and you have no idea what was going on, but we were explained how it worked and that made a lot more sense.* P7FG2F

Participants often describe difficulty in interpreting US images; they found it difficult to identify familiar anatomy when illustrated in grayscale, particularly when changing the orientation of the probes. Some of the participants found it positive to identify the structures. Although some participants mentioned that it took them a while to get used to interpreting the US image on the screen.

> *I found it really positive in identifying the structures. While using the ultrasound, you could really see the structures and it really matched the picture.* P4FG1M

> *The image that pops up on the device itself, took a bit of time to understand the view you're looking at.* P5FG1M

> *It was very difficult in the beginning to orientate yourself because it is in black and white [grey scale] and it looks very different from what we used to [in the cadaver], but once we could find the landmark and orientate ourselves, I found it was a lot easier.* P6FG2F

> *It might have taken a few manoeuvres to get used to the machine, but once we got the image on the screen it was pretty easy to identify the structures.* P10FG3F

Most participants mentioned that they struggled to identify the structures because of the grayscale of the sonogram but commented on the value of turning on the colour (Doppler) mode on the machine to assist them with identifying the structures.

> *It is all grey and it's difficult sometimes to see exactly what you're looking at.* P11FG3F

> *At first, it was extremely difficult because everything is in black and white [grey scale] and you're not exactly sure what each circle or each line represents. But once the colour was added on, you could find the landmark. It was a lot easier to find structures.* P7FG2F

Although the participants were uncertain and afraid in the beginning to use the US device, using the device significantly increased confidence with and knowledge of US as well as sonogram interpretation.

Excitement to use the US device

The participants were enthusiastic to use the US and there was excited anticipation in the classroom prior to using it. The participants also mentioned the excitement of using the US for the first time and the novelty of it made them excited.

> *It was our first time ever encountering ultrasound: we were all very excited. Because I know, for days before the practical, we were all talking about the ultrasound, and we were excited.* P8FG2F

> *It was also quite exciting to use ultrasound. You know days before, we were excited.* P6FG2F

> *And it is definitely an exciting new thing that we haven't done before, so the enthusiasm was also there.* P10FG3F

The participants perceived the use of US as an innovative, stimulating, and engaging manner to stimulate learning of living and clinical anatomy.

Hands-on experience of using the US

The students were encouraged to use the device to scan themselves and each other. Many of the participants commented on how they experienced using the device and how it had helped them.

> *Physically using it did help a lot.* P3FG1M

> *I think it was nice to be exposed to and use it and see it and just learn from the experience.* P6FG2F

> *And we could do it ourselves, hands-on and look at different students' neck regions and see maybe if there was variation.* P10FG3F

A few participants also commented on the hand-eye coordination of using the US and how the hands-on experience of matching their hands with the screen and incorporating that knowledge into learning anatomy.

> *On the one hand, you used your hand-eye coordination to try and orientate where you were on the neck, but while looking at the screen, it incorporates a lot more senses than just reading for example or just looking at a picture.* P7FG2F

> *And even during the ultrasound, when you perform it, you must have an idea of where the [anatomical] structures are. It matches your hand/eye coordination with knowledge.* P8FG2F

Participants also commented on how the hands-on experience might aid them to remember the theory better.

> *For me personally, doing things hands-on and seeing exactly what you need to see, using whatever machinery or equipment you need to use, it really does help with remembering it because it's a physical activity, you are getting involved with your hands.* P11FG3F

One participant commented on how shocked they were that the device was so compact and portable.

> *What I found really interesting was that the whole US machine is so small. It's not these big kind of ultrasound machines that you can see in like the movies or like in doctors' offices.* P4FG1M

The hands-on experience of using the device promoted participants to feel that they will retain anatomical knowledge longer. A more haptic approach was incorporated for the students during teaching sessions in anatomy due to the small size of the class.

Discussion of theme six: The technical and affective experience of using the US

US images are mostly grey except the Doppler mode, which is coloured, to show the vascularity and blood flow (Mumtaz et al., 2016). The US images were difficult to interpret at first. The students needed time to interpret the images and once the basics were understood, the images were better appreciated and interpreted by the students (Mumtaz et al., 2016). Participants felt more confident in identifying anatomical structures as they become more familiar with the US (Dreher, Dephilip & Bahner, 2014). This could be due to students' improved knowledge of anatomy, with US, or both. The students were satisfied with the sessions, even though they found the anatomical structures difficult to identify due to inexperience with sonograms (Allsop, et al., 2020). However, I believe that the process of learning to understand the orientation of the scan and the probe is significant as it will train students to comprehend complex 3D relations and spatial understanding between anatomical structures (Ivanusic, Cowie & Barrington, 2010).

Motivating students to be active participants in their learning by using the US themselves, made the session more relevant to the students. This form of contextualized learning is effective for adult learners to encourage a deeper understanding and promote retention of facts (Royer, Kessler & Stowell, 2017). The hands-on experience of teaching was perceived as enjoyable and educational as learning-by-doing is mostly regarded as an effective approach to learn (Lombardi, 2007). By actively using the US, students are linking their textbook knowledge to the study of living anatomy, to obtain views of dynamic regions, identify anatomical structures, and link deeper structures with surface anatomy (Royer & Buenting Gritton, 2020). Furthermore, converting a 2D view into 3D spatial orientation (Theme 2) involves the coordination of the visual and tactile senses (Knobe et al., 2012). These intricate coordinating skills may support memory retention (Theme 4). These results resembled preceding studies where students found US to be an innovative approach and a successful way to teach anatomy (Ivanusic, Cowie & Barrington, 2010; Moscova et al., 2015; Bullen et al., 2020).

5. CONCLUSION

This chapter presents a conclusion on the research report, emphasising its most important findings. Strengths and limitations of the study are considered, and future study recommendations are made.

5.1 SUMMARY OF FINDINGS

This study aimed to explore undergraduate clinical anatomy students' perceptions on the use of US as an add-on to cadaveric dissection to enhance the learning of living anatomy as well as cross-sectional anatomy. A qualitative design within an interpretive/constructivist paradigm was used to explore perceptions that are expected to advise us about educational practice. The research indicated that it is feasible and advantageous to include US sessions as an add-on to the teaching of anatomy during practical dissection sessions with undergraduate clinical anatomy students. The clinical anatomy students embraced this novel tool and were actively engaged. This innovative, student-centred approach to anatomy teaching also adds to the rapidly evolving technological advances in health professions education.

The use of innovative technologies such as US increases the interest of students, enables real-time viewing of dynamic anatomical relationships, enhances spatial ability, and allows students to gain skills and competencies in their learning process. There appears to be an acquired skill in being competent in interpreting sonograms and to integrate the anatomy seen to existing anatomical knowledge. Students were excited by the novelty of using US during the practical session. In addition, students valued the added benefit of seeing living anatomy to supplement their learning in the anatomy cadaveric laboratory and link the anatomy with clinical practice and postgraduate anatomy research. However, dissection continues to be irreplaceable for the identification of complex anatomical structures and enables 3D perspective and tactile perception which cannot be found with 2D US.

This study also further emphasizes the importance of a multimodal teaching approach to optimize student learning, as students appear to learn more effectively when mixed educational methods and system-based approaches are integrated. Students appreciated the opportunity to correlate the cross-sectional US images together with the dissected or prosected specimens. The combination of the 2D US with the 3D cadaveric dissection or prosections enhanced their spatial awareness in anatomy. Feedback revealed that students would like more US sessions, more time, and more opportunities to be hands-on. The results of this study align with that of other institutions that have also run similar sessions with US.

US technology is added to human anatomy instruction in many medical sciences curricula. Anatomy teaching using US can act as a bridge, integrating anatomy learning and clinical practice by assisting students to apply anatomical knowledge. Nonetheless, these techniques have not routinely been transferred to anatomy modules for non-medical graduate-level courses. This study showed that clinical anatomy (non-medical) students connected the US sessions' learning objective to their postgraduate interests and future careers.

Reflecting on the experience of implementing US within practical session, the most noticeable aspect was the increased engagement of the students. The US session inspired interest in anatomy. Additionally, the student-centred approach excited students and motivated them to learn. I have also found US to be a stimulating add-on to my teaching armamentarium and believe that it is a valuable tool in reaching the current generation of anatomy students. However, I do believe that 3D anatomy is the basis of understanding 2D cross-sectional images and that the dissection hall, where students can visually inspect cadaveric specimens side by side with 2D US images, is the best place to learn spatial understanding. Lastly, the anatomy educators in the division were also enthusiastic to learn how to use the US and to incorporate it in other anatomy programmes.

5.2 STUDY STRENGTHS AND LIMITATIONS

The findings provide valuable insight into undergraduate clinical anatomy students' perceptions of the use of US in their learning of anatomy. In addition, the results provide new insights, as no data exist on the use of US in the aid teaching and learning anatomy at Stellenbosch University. To date, no literature could be found of qualitative studies on the topic of anatomy.

The limitations of this study relate to the small sample size in one setting being used. However, current literature does not indicate an optimal number of participants for an exploratory descriptive study of this nature to increase the trustworthiness of the findings. Furthermore, using one research setting, namely Stellenbosch University, limits the generalisability of the results. Nevertheless, the results of this study resonate with previous research conducted on this topic. Also, there might have been bias towards positive responses as some of the questions in the virtual focus groups utilized positive wording. However, participants were encouraged to include both positive and negative feedback.

The study was limited to students' perceptions and did not measure if the students performed better academically after US sessions; this makes it difficult to deduce its value in terms of grades or assessment marks. Furthermore, Royer, Kessler, and Stowell (2017) noted that there are no formal or confirmed means of determining students' knowledge of anatomical concepts hand in hand with US

instruction. A great starting point for developing a more standard evaluation is modifying the assessment methods used to test student's comprehension of gross anatomy concepts relevant to US sessions (Bullen et al., 2020). This can be accomplished by adding US images in assessments for students to label.

The study was also restricted to teaching neck and thyroid anatomy with US, and it would be valuable to investigate if student perceptions on the use of US technology to learn the anatomy of different body regions would be just as positive. Another limitation was the amount of time available for the US session as the students spent only a short amount of time using the US. Therefore, their understanding of the US modality was limited after such a brief introduction, but the feedback they gave, indicated that they felt confident with studying anatomy in this innovative way.

Traditional embalming, such as used in the Division of Clinical Anatomy, restricts the ability to scan the cadavers; however soft embalming techniques may allow the imaging of a cadaver (Royer & Buenting Gritton, 2020). On the other hand, the dynamic facet of US will be lost when imaging a cadaver, even when using different embalming techniques.

5.3 FUTURE DIRECTIONS

The findings of this study can further lead to an investigation of the perspectives of anatomy educators on the implementation of US training as an additive to traditional teaching methods in anatomy. Further studies should also include medical students, as US is a required skill for future use in clinical practice. In addition, a follow-up on the cohort of medical students during their clinical years would be meaningful, to establish whether they perceived that the incorporation of ultrasound during basic science modules better prepared them for the clinical setting.

Further research involving the use of more portable, handheld, and affordable US devices will need to be done to ascertain their usefulness in educational settings. A recent study found that virtual reality anatomical training could help US training by supporting a better awareness of the spatial relationships of anatomical structures and an improved understanding of sonograms (Hu et al., 2020). The Division of Clinical Anatomy is in the process of acquiring virtual reality equipment and applications for anatomy education, thus would be meaningful to investigate the influence of virtual reality anatomy training on US competency development.

With continued technological advancement and collaboration between teaching staff, there will be fewer challenges in successfully implementing US sessions. Anatomy educators and other appropriate specialists such as clinicians with US training, sonographers and radiologists, ideally

should collaborate to create an anatomy-centred US syllabus. Furthermore, increasing the availability of faculty development opportunities for anatomy educators might increase the implementation of US in non-medical and medical programmes. Positive outcomes have been demonstrated when US training has been developed for anatomy educators to build US scanning proficiency.

An unforeseen factor at the time of this research was the adjustments to face-to-face teaching considering the Covid-19 pandemic. Universities around the globe transformed to concentrate more on online teaching and learning, consequently leading to the hands-on experience being lost, thus it will also be worthwhile exploring options for maintaining US teaching, including streaming of US sessions and additional online materials (subject to the required ethical approvals). Changes to anatomy education are expected to be impacted upon even after the Covid-19 pandemic and consequently, we anticipate seeing additional transformation and innovation in US delivery in anatomy learning in the nearby future.

6. REFERENCES

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Appendix A

PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM

TITLE OF RESEARCH PROJECT:	
Learning cross-sectional anatomy using ultrasound: perspectives of undergraduate clinical anatomy students	
DETAILS OF PRINCIPAL INVESTIGATOR (PI):	
Title, first name, surname: Ms Janine Correia	**Ethics reference number:** S20/02/051
Full postal address: Room F165; Fisan Building, Tygerberg Medical Campus, Francie van Zijl Drive	**PI Contact number:** 0219384017

We would like to invite you to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the researcher any questions about any part of this project that you do not fully understand. It is important that you are completely satisfied that you clearly understand what this research entails and how you could be involved. In addition, your participation is **entirely voluntary,** and you are free to decline to participate. In other words, you may choose to take part, or you may choose not to take part. If you say no, it will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part initially.

The Health Research Ethics Committee at Stellenbosch University has approved this study**.** The study will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki, the South African Guidelines for Good Clinical Practice (2006), the Medical Research Council (MRC) Ethical Guidelines for Research (2002), and the Department of Health Ethics in Health Research: Principles, Processes and Studies (2015).

What is this research study all about?

- *The study will take place at the Division of Clinical Anatomy. All the third-year clinical anatomy students will be invited to participate. Virtual focus group interviews of 4 – 6 students will be conducted after the ultrasound (US) session of 20 October 2020 on Microsoft Teams. Four focus group interview sessions will take place.*
- *The intention of the study is to explore third-year clinical anatomy students' perception of the use of US in anatomy. US as an add-on to dissection may strengthen existing anatomical understanding, improve visual understanding of anatomy and encourages interest in anatomy.*
- *The US sessions will take place during the practical dissection sessions of the neck region. A 15 min introductory lecture before the ultrasound session will be placed on SUNLearn. Each student will then get a chance to use the US device on the cadaver on 20 October 2020 and try to identify the cross-sectional structures and linking that to what they are currently studying.*

Why do we invite you to participate?

- *The selection criteria for this study led to us inviting you to participate. As you are a clinical anatomy student learning anatomy for future application in your clinical work, you are a valuable source of information needed to conduct this study. Your evaluation of any intervention, such as using ultrasound for teaching, is essential for educators to better understand how your learning experience was affected.*

What will your responsibilities be?

- *To participate in virtual focus group interviews and answer the questions as truthfully as possible.*

Will you benefit from taking part in this research?

- *There are no personal benefits from the study as such; however, reflection and reflexivity would usually be processes that lead to a degree of personal satisfaction and further learning.*
- *In the event that you are involved in teaching students as future clinicians or anatomists, metacognitive awareness would be advantageous in facilitating learning.*
- *The primary benefit of insight gained would be too interested practitioners in the field of HPE, particularly Anatomy educators.*

Are there any risks involved in your taking part in this research?

- *No risk involved.*

If you do not agree to take part, what alternatives do you have?

- *Participation is entirely voluntary, and you are free to decline to participate.*

For non-sponsored health research or research sponsored by Stellenbosch University, where the Principal investigator is a staff member or student at Stellenbosch University; or for NIH/US government funded research:

- Stellenbosch University will provide comprehensive no-fault insurance and will pay for any medical costs that came about because participants took part in the research (either because the participant used the medicine in this study or took part in another way). The participant will not need to prove that the sponsor was at fault.

Will you be paid to take part in this study and are there any costs involved?

- *You will not be compensated to take part in the study; however, as a small token of our appreciation, you will receive a gift.*

Is there anything else that you should know or do?

- *You can phone the Health Research Ethics Committee at 021 938 9677/9819 if there still is something that the PI has not explained to you, or if you have a complaint.*
- *You will receive a copy of this information and consent form for you to keep safe.*

Declaration by participant

By signing below, I …….……. agree to take part in a research study entitled: Learning cross-sectional anatomy using ultrasound: perspectives of undergraduate clinical anatomy students

I declare that:

- I have read this information and consent form, or it was read to me, and it is written in a language in which I am fluent and with which I am comfortable.
- I have had a chance to ask questions and I am satisfied that all my questions have been answered
- I understand that taking part in this study is **voluntary,** and I have not been pressurised to take part.
- I may choose to leave the study at any time and nothing bad will come of it – I will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the study doctor or researcher feels it is in my best interests, or if I do not follow the study plan that we have agreed on

Signed at (*place*) .....…..……. on (*date*) ……...…….2020.

Signature of participant **Signature of witness**

Declaration by investigator

I *(name)* …….…… declare that:

- I explained the information in this document in a simple and clear manner to …….
- I encouraged him/her to ask questions and took enough time to answer them.
- I am satisfied that he/she completely understands all aspects of the research, as discussed above.
- I ~~did~~/did not use an interpreter. (*If an interpreter is used then the interpreter must sign the declaration below.)*

Signed at (*place*) .....…..……. on (*date*) ……...……. 2020.

Signature of investigator **Signature of witness**

Permission to have all anonymous data shared with journals:

Please carefully read the statements below (or have them read to you) and think about your choice. No matter what you decide, it will not affect whether you can be in the research study or your routine health care

When this study is finished, we would like to publish the results of the study in journals. Most journals require us to share your anonymous data with them before they publish the results. Therefore, we would like to obtain your permission to have your anonymous data shared with journals.

Permission for sharing samples and/or information with other investigators:

Please carefully read the statements below (or have them read to you) and think about your choice. No matter what you decide, it will not affect whether you can be in the research study or your routine health care.

To do the research, we have discussed, we must collect information about your opinion of the matters discussed in the above consent form. Once we have done the research that we are planning for this research project, we would like to store your information. To protect your privacy, we will replace your name with a unique study number. We will only use this code for information about you. We will do our best to keep the code private. It is, however, always possible that someone could find out about your name, but this is very unlikely to happen. Therefore, we would like to ask for your permission to share your samples and information with other investigators.

Tick the Option you choose for anonymous data sharing with journals:

I agree to have my anonymous data shared with journals during publication of results of this study

☐

OR

I do not agree to have my anonymous data shared with journals during publication of results of this study

☐

Tick the Option you choose for sharing samples and/or information with other investigators:

I do not want my information to be shared with other investigators

☐

My information may be shared with other investigators for further analysis and future research in a field related to research of anatomical education

☐

Signature_____

Appendix B

VIRTUAL FOCUS GROUP SCHEDULE

Time	Wednesday, 21 October	Thursday, 22 October
10:00	Group 1 Five participants	Group 2 Three participants
11:30		Group 3 Three participants

The virtual focus group interview schedule is outlined below (based on Breen 2006).

1. Welcome and thanks for participating.
2. An overview of the topic.

   Ultrasound use has expanded dramatically among the medical specialities for diagnostic and interventional purposes, due to its affordability, portability, and practicality. This imaging modality, which permits real-time visualization of anatomic structures and relationships in vivo, holds potential for undergraduate anatomy students.

   Furthermore, living anatomy, as an educational component, is a neglected entity in anatomical sciences education. Students frequently find it demanding to visualize the functioning living anatomy of the human body therefore the implementation of ultrasound as an additional learning strategy may strengthen existing anatomical understanding and improve visual understanding of anatomy.

3. Statement of the ground rules of the virtual focus group, and assurance of confidentiality.
   a. Assurance of confidentiality
   b. Raise-hand's function, refer to students by initials
4. Start recorder.

   The focus group questions/discussion (beginning with general experiences and progressing to specific problems).

   a. How did you experience the ultrasound sessions during the dissection session?
   b. What about the ultrasound sessions did you perceive as positive?
   c. What about the ultrasound sessions did you perceive as negative? How can we improve the sessions?
   d. How did you find the pre-ultrasound material that was posted on SUNLearn?
   e. Cross-sections are two-dimensional views of gross anatomical structures in transverse planes. How do you think ultrasound benefited (or not) your learning of cross-sectional anatomy?
   f. How do you feel about using the ultrasound as an add-on during dissections to study living anatomy?
   g. How did you find the identification of the anatomical structures while using the ultrasound?

h. Do you think using ultrasound will create a link between undergraduate anatomy and clinical relevance?

i. How did you experience the hands-on involvement of the ultrasound session?

j. Do you have any closing statements on the ultrasound and its use in your teaching and learning anatomy?

5. Stop recorder.

Appendix C

HREC ETHICAL APPROVAL LETTER

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

Approval Notice

New Application

19/06/2020

Project ID: 13353

HREC Reference No: S20/02/051

Project Title: Ultrasound in teaching and learning Human Anatomy

Dear Ms. Janine Correia

The **New Application** received on 24/02/2020 10:54 was reviewed by members of **the Health Research Ethics Committee** via **expedited** review procedures on 19/06/2020 and was approved.

Please note the following information about your approved research protocol:

Protocol Approval Date: 18 June 2020

Protocol Expiry Date: 17 June 2021

1. Kindly note that although the study has been granted ethics approval, the study may not proceed during the current national lockdown as an embargo has been placed on studies that require face-to- face interaction with research participants and/or put participants in harm's way in the time of COVID19 – either potentially or.
2. HREC will publish on the HREC website a date when the said embargo is to be lifted taking into consideration the best interest of participants and national interests around COVID-19.
3. If you wish to continue with the study, please consult with the Health Research Ethics Office staff to explore requirements and possibilities

Please remember to use your Project ID 13353 and Ethics Reference Number S20/02/051 on any documents or correspondence with the HREC concerning your research protocol.

Please note that the HREC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process. **After Ethical Review**

Translation of the informed consent document(s) to the language(s) applicable to your study participants should now be submitted to the HREC.

Please note you can submit your progress report through the online ethics application process, available at: Links Application Form Direct Link and the application should be submitted to the HREC before the year has expired. Please see *Forms and Instructions* on our HREC website (www.sun.ac.za/healthresearchethics) for guidance on how to submit a progress report.

The HREC will then consider the continuation of the project for a further year (if necessary). Annually several projects may be selected randomly for an external audit.

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility, permission must still be obtained from the relevant authorities (Western Cape Department of Health and/or City Health) to conduct the research as stated in the protocol. Please consult the Western Cape Government website for access to the online Health Research Approval Process, see: https://www.westerncape.gov.za/general-publication/health-research-approval-process. Research that will be conducted at any tertiary academic institution requires approval from the relevant hospital manager. Ethics approval is required BEFORE approval can be obtained from these health authorities.

We wish you the best as you conduct your research.

For standard HREC forms and instructions, please visit: Forms and Instructions on our HREC website https://applyethics.sun.ac.za/ProjectView/Index/13353

If you have any questions or need further assistance, please contact the HREC office on 021 938 9677.

Yours sincerely,

Mrs. Brightness Nxumalo
HREC 2 Coordinator

National Health Research Ethics Council (NHREC) Registration Number:

REC-130408-012 (HREC1)·REC-230208-010 (HREC2)

Federal Wide Assurance Number: 00001372
Office of Human Research Protections (OHRP) Institutional Review Board
(IRB) Number: IRB0005240 (HREC1)·IRB0005239 (HREC2)