Nature and Challenges in the Teaching of Anatomy from a Global Perspective

Ana Yoe Cheng Chang Chan

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Nature and Challenges in the Teaching of Anatomy from a Global Perspective

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Ana Yoe Cheng Chang Chan

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te Leon, Nicaragua

Promotoren:
Prof. dr. Th.J. ten Cate
Prof. dr. R.L.A.W. Bleys

Copromotor:
Dr. E.J.F.M. Custers

Beoordelingscommissie:
Dr. J.L. Browne MSc PhD
Prof. dr. R. Kusurkar
Prof. dr. A. van Royen-Kerkhof
Prof. dr. D. Salvatori (voorzitter)
Prof. dr. J.P.J. van Schaik

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Human Anatomy Across Time

Anatomy is the science that studies the structure of organized bodies; etymologically, the word anatomy is derived from Greek and means recut ("*ana*" return and "*tomos*" cut), as its primary method of study was the dissection (1–5).

Gross human anatomy is one of the oldest branches of medical knowledge. Therefore, from a historical point of view, human anatomy can be considered one of the fundamental pillars of medical training (6).

Knowledge of anatomy dates back to about five hundred years before Christ (BC) with Alcmeon of Crotona, who dissected animals (7). Later, in the Alexandrian school (III century BC), thanks to the works of Erasistratus of Ceos and Herophilus of Chalcedon, who systematically practiced human dissections, anatomical dissection became the primary means of learning macroscopic anatomy (8). Sadly, their findings were not incorporated into the evolution of anatomical sciences due to a fire that destroyed all the records of Alexandria, producing stagnation in the field of anatomy for the next thousand years (9,10).

During this post-Alexandrian period, when anatomical dissection on human bodies was considered heresy and prohibited for religious reasons, anatomical knowledge was mainly influenced by the work of the Greek and Roman physician Galen de Pergamon, also known as Claudius Galenus (II century AD), who practiced animal dissections and wrote the "Treatise on Anatomy," which, despite numerous errors in its description, especially those concerning the anatomy of the organs, was widely distributed, and taught for more than 14 centuries until the Middle Ages (10,11).

In the Renaissance, with the establishment of universities and medical schools in Europe and the renewal of interest in the human body, anatomy as a science emerged, as it was part of a popular culture fascinated by the inside of the human body. Thus, anatomical illustrations and dissection theaters emerged, where anatomists began to dissect criminals' human bodies to investigate their internal structures and to entertain the public. Its popularity extended to contemporary artists such as Leonardo Da Vinci (1452 – 1519) and Michelangelo Buonarroti (1475 – 1564), who closely linked the science of anatomy with works of art. Thus, anatomy was considered an artistic and spiritual exploration of life, and it also significantly contributed to the realistic representation of the human form (7,8,10,12). In this period, Galen's errors were exposed thanks to Andreas Vesalius (1514 – 1564), born in Brussels as Andries van Wezel, and his work "*De humani corporis fabrica*." This meant a significant change in medical sciences in general as the dogmatic teaching of the ancient books became learning by direct observation, laying the foundations of the current scientific methods. In this context, the bodies were considered "books"; students learned to read by observation (7,11).

Another historical period of significant development in anatomy was the 17th century, when, due to the substantial increase in anatomy students, difficulty arose in

acquiring enough cadavers. As a result, wax anatomical models sculpted by direct observation of dissected corpses emerged as the surgeon Guillaume Desnoues (1650 – 1735), with the help of the artist Gaetano Giulio (1656 – 1701), created the first realistic and colored anatomical wax models (8). In addition, remarkable advances in anatomy sciences were the discovery of blood circulation by William Harvey (1578 – 1657), who combined the Italian anatomical tradition with experimental science born in England, and the use of the microscope in anatomical sciences by Marcello Malpighi (1628 – 1694), founder of histology (10).

Most of the usual anatomical details at the macroscopic level were already established in the 18th century, mainly thanks to the increasingly detailed study of dissection techniques. Consequently, the divisions of anatomy that we know today began to emerge due to the constant scientific explorations of the doctors and anatomists of the time. Raymond de Vieussens (1641 – 1715) began to correlate the clinical findings of his patients (recorded during their lifetime) with observations made during the autopsy of the same patient after his death. Thus, pathological anatomy was born, the anatomical-clinical study of the corpse, providing a link between the practice of anatomy and a wide range of clinical conditions. Later, in the 19th century, microscopic anatomy (histology) emerged, thanks to the work of Xavier Bichat (1771 – 1802), who was the first to explore anatomical details based on the different characteristics of tissues as essential elements of organs (10).

The 20th century represents the beginning of the metamorphosis of anatomical sciences. Throughout this century, several changes occurred, both in anatomy as a science and in teaching anatomy. Regarding anatomy as a science, medical imaging methods such as X-rays, ultrasound, computed tomography, and magnetic resonance facilitate direct visualization of pathological conditions around anatomical structures and allow the exploration of living anatomy, giving rise to accurate, individualized anatomy with clinical orientation (9,10). Other changes that occurred were the emergence of plastination, introduced by von Hagens in 1977, as a new method of preserving human tissues that offers easy handling, odorless and convenient storage of dissected anatomical pieces, making it preferable to formalin-fixed material (8,12,13).

Changes in anatomy teaching occurred with the changes in the education disciplines in the second half of the 20th century. These changes were expressed as multidisciplinary, integrated, problem-based, and self-directed approaches, emphasizing the understanding and application of knowledge rather than rote memorization of the structures. Active learning methodologies, such as body painting and computer-assisted learning, were introduced to complement lectures and dissection (7,9,12).

In the 21st century, the primary influences on anatomical sciences are technological advances such as virtual reality, augmented reality, and artificial intelligence. This allowed anatomical structures to be repeatedly explored through high-end software systems without risk of damaging or injuring these structures, thus

facilitating access to human tissue as a valuable resource in terms of research (9,10). In the educational field, this has been expressed with the implementation of teaching approaches such as e-learning and mobile learning and the use of social networks such as YouTube, Facebook, and WhatsApp (14–17), taking advantage of the benefits offered by ubiquitous learning (at any time and any place), which has allowed students to learn continuously and adaptively, promoting autonomy, personalization and the development of digital skills (18).

The 21st century has also changed the source of corpses used for dissection, using more unclaimed corpses from the morgue and, latterly, the donation of corpses (8). In addition, anatomical sciences serve as teaching scenarios for ethical aspects and professionalism in medical schools. It is the first educational environment where students interact with their educators, peers, and body donors/patients, attributing dignity to the donated body and extending the honors of living people to their mortal remains (9, 10, 12, 19, 20).

The evolution of anatomy over time has been one of the pillars of the advancement of medical sciences. Given that it established the scientific and linguistic bases of medicine, oriented the culture of medicine towards health and normality, and promoted observation and experimentation as an approach to scientific study. Thus, supplanting the educational approach based on pre-established texts and ideas.

1.2 Didactic resources in anatomy education

Didactic resources upgrade anatomy learning; for centuries, the essential tools for instructing anatomy have been lectures, tutorials, textbooks, cadaveric dissections, and demonstrations from prosected specimens. These involve visualization, which is necessary for procuring anatomical knowledge (21,22).

The earliest anatomical texts were purely descriptive and were not illustrated; the available literature provides little information on using illustrations during this early period of human anatomy as a science. The first signs of anatomy texts date back to ancient Greece (4th century BC) when Herophilus of Chalcedon and Erasistratus of Ceos performed human cadaveric dissections and documented anatomical details closer to the natural structures of the human body. Similarly, Galen's anatomical writings were based on textual descriptions; this characteristic continued until the Middle Ages, when merely descriptive anatomical works without illustrations were still observed, such as those written by Mondino de Luzzi in 1316. (23).

In the late Middle Ages, Guido da Vigevano (1280-1349), a student of Mondino de Luzzi, was the first to use images to illustrate his anatomical descriptions. His manuscript drawings began a new trend that became increasingly popular over the following centuries. Anatomical drawings during this period were primarily unrealistic and rudimentary, possibly due to a lack of exact anatomical information. This practice of

accompanying anatomical descriptions with illustrations was intensified during the Renaissance, characterized by the participation of renowned artists and painters (such as Leonardo da Vinci and Michelangelo Buonarroti) who impregnated the anatomical details with artistic features. In this period, it is essential to highlight the contribution of Vesalius, who established the importance of using illustrations with anatomy texts, which allowed anatomists to escape the dominance of descriptive texts that had prevailed for centuries among scholars (23).

Starting in the 16th century, the trend of illustrated books continued to rise; by then, the images used were more realistic and allowed anatomy to be taught in increasingly more detail, thus highlighting its importance. Among the books of this period, we can mention those by Albinus, Monro, William Hunter, Geronimo Fabricio, Andrea Cesalpino, and Realdo Colombo (24).

In the late 18th and early 19th centuries, anatomists such as John Bell, Sir Charles Bell, and Cloquet, gifted with artistic skills, began to prepare their illustrations. Their efforts contributed significantly to improving the perspective of anatomical art concerning the representation of anatomical knowledge. Testut, Gray, and Rouviere were among the anatomy book authors from this period (23).

In the 20th century, prominent anatomists produced textbooks to meet the needs of their students in their respective countries. These anatomy texts were accompanied by the publication of anatomical atlases with excellent drawings and photographs. Among them were Netter, Prometheus, Rohen-Yokochi, Sobotta, and Wolff Heidegger (24).

Technological advances during the latter part of the 20th century led to computer-assisted, digitally enhanced images. During the last quarter of the 20th century, books appeared that used these techniques to emphasize the clinical applications of anatomical knowledge. The books contain pictures obtained with X-rays, ultrasound, CT scans, and magnetic resonance imaging. Although these books were less descriptive than in the past, they were supported by clinical foundations to make anatomy more exciting and relevant to students. Bringing them closer to the inside human body and providing information about the living being for physical examination purposes (surface anatomy) and applied anatomy (23,24).

At the beginning of the 21st century, the advancement of technology and the communication revolution rapidly disseminated information, impacting anatomy education and its available teaching resources, including images. More recently published books focus on clinical anatomy and are supported by complementary computer material, mainly in CD form. Another evolution in the teaching resource is the electronic book, with multimedia components, whose interaction characteristic attempts to promote self-directed learning (21–24).

Due to the Internet's adaptability and ease related to time and space barriers, teaching resources for anatomy are characterized by the strong presence of information

and communication technology, guiding the students toward self-directed learning. Among the teaching resources used to support the teaching of anatomy are tutorial videos, video streaming, digital platforms, and social networks such as YouTube, virtual reality, and augmented reality software. Those aim to improve further the student's experience in the classroom or dissection room (21,22).

1.3 Anatomy Education around the world

In the last decades, education in gross anatomy has generated interest and concern globally as it has been affected by curricular changes in medical education. Several studies on the main approaches to anatomy teaching can be found in the medical education literature, which all have three aspects in common: (a) the reduction in the number of hours devoted to teaching anatomy, (b) the use of corpses as the primary teaching/didactic resource, either by dissection or prosection with the inherent difficulties in acquiring enough cadavers for dissection, and (c) the use of complementary tools ranging from anatomical models, audiovisual aids, and different (software, slides, videos, radiological images, learning management systems, artificial intelligence).

Examples in Europe

The traditional gross anatomy teaching in the United Kingdom (topographic anatomy taught by didactic lectures, tutorials, and dissection of bodies under the supervision of instructors) has mainly been replaced by other methods. Current approaches to teaching anatomy include, qualified in 2007 by Raffery in order of effectiveness (25): prosection (best), problem-based learning (PBL), special studies modules (components students select) including electives courses, CD ROMs, plastic models (worst).

In the UK, most medical schools prefer to use donated bodies as a critical tool for understanding the structure and anatomical variations. Still, dissection is almost always used alongside other tools such as imaging, peer examination, simulation, and computer-generated images. This suggests that successful sensory learning requires a combination of methods (26).

Due to the significant development technology has had in recent decades and its considerable influence on daily life, it is expected that researchers in medical education will begin to investigate the role of various electronic devices in the teaching and learning process. Examples from Western European universities that have implemented digital drawing via tablet (Germany) and augmented reality (Netherlands) suggest that new technologies facilitate the anatomy learning process and can positively affect the learning outcome. This is mainly because it alleviates the cognitive load and is attractive to students, thus increasing their motivation to study anatomy (27,28).

A Polish study indicates that medical students prefer dissection and using prosected specimens to study gross anatomy. Multimedia tools are mainly utilized for radiological anatomy to review and edit the correct names of anatomical structures using precise anatomical terminology (29).

At a university in France, anatomy professors proposed using the “article critique” associated with the classical teaching method. The authors consider the critical review of articles an excellent approach to applied anatomy. As it is known, anatomy constitutes a fundamental basis for clinical medical sciences, and in recent decades, the trend has been toward integrating clinical problems into the anatomical course. As a problem-based learning method, “article critique” could be a pertinent approach to clinical anatomy or applied anatomy (30).

A study conducted at a university in Russia emphasizes the use of radiological techniques (CT and ultrasound) and the clinical importance of anatomical findings, highlighting applied anatomy as an educational approach (31).

Examples in Asia

A survey in India conducted among medical students indicated that a longer course (18 months) of gross anatomy is needed to understand the subject better. They expressed the desire to have more emphasis on teaching gross anatomy with clinical orientation. Moreover, most participants reported that the dissection helped them understand the anatomy and should not be replaced by a prosection, as the information obtained from dissections of cadavers was more complete than that obtained via prosection or any other learning model (32).

In some Asian countries, including China and Japan, human dissection was considered to conflict with the teachings of Confucius because it damaged the gifted body and was associated with impurity. China influenced the Japanese's early thoughts about human anatomy and was later influenced by the Netherlands and Germany (33).

The influence of Western countries’ medical schools on medical education has been consolidated in recent decades. According to a national survey in mainland China in which 65 medical schools participated to examine the state of anatomy education in the last 30 years, 54% have adopted PBL, and to a lesser extent, team-based learning (15%) and the flipped classroom (10%). Another interesting finding of this study is that 75% of the participating schools have implemented information technology in anatomy teaching, highlighting its usefulness for understanding the spatial relationships of the structures of the human body as a whole, alleviating the problem of the lack of corpses and specimens (34).

One study in 2012 showed that most anatomists in Iran use lectures mainly. Only 3% use interactive multimedia, while over 80% believe dissection is the best way to teach gross anatomy (35).

Key recommendations from a 2012 study in Singapore include body painting, clay, and plastination to facilitate anatomy learning and the implementation of a body donation program (36).

Part of the evolution of anatomy education is to be a setting for teaching ethics and professionalism, as demonstrated in Taiwan with its Buddhist Tzu Chi program, “The Silent Mentor,” where the identity of the training corpses is an essential element in medical pedagogy, deliberately involving the student with the family of the deceased and aiming to build career-long relationships between students and their 'Silent Mentors.' When students have finished dissection, they suture the cadaver again to restore its appearance. They dress it and participate in a commemorative ceremony, thus expressing their gratitude and promoting respect and appreciation for the human body (20,37).

Examples in Australasia

Medical schools in Australia use a clinically integrated anatomy teaching approach, which could benefit anatomical and surgical educators (37,38). They also implement PBL, lectures, and practical activities structured around case studies that attempt to integrate basic science knowledge. Anatomy teaching uses prosecuted specimens, computer-generated models, and medical images (39,40).

Studies performed in New Zealand indicate that plastinated materials are widely used in many anatomy courses, possibly because the anatomical details available due to the flexibility of the tissues are more apparent in these specimens (41).

Examples in Africa

Many African countries (Egypt, Malawi, Uganda, Zambia, Mozambique) with traditional curricula use practical/laboratory sessions and lectures, with cadaver dissection being a constant feature in anatomy education. Dissection is complemented by prosection and self-study. Other resources include anatomical models, museums, histological slides, computer labs, and cross-sectional radiological images. Between 200 and 500 hours are allocated for anatomy education. Meanwhile, some South African Republic medical schools apply the PBL curriculum with vertical and horizontal integration with dissection, a teaching tool complemented by anatomical models and histological slides (42).

In Namibia, anatomy education is taught alongside other sciences, such as physiology and biochemistry. It includes clinical anatomy through simulations, case studies, and models and utilizes dissection, lectures, histology laboratory, and medical imaging (43).

Examples in America

Studies in the United States of America indicate that most gross anatomy courses consist of lectures and laboratory dissection/prosection (44). Although dissection continues to be the most prominent teaching method, most physicians report an increase in the use of digital techniques in teaching radiological anatomy (45).

Conversely, studies in Canada reflected the importance of radiological anatomy (81%), surface anatomy (45%), dissection (40%), lectures (36%), and prosection/plastination (20%) as teaching methods, and 87% of Canadian medical schools reported using computer-aided learning (CAL) in a complementary way in teaching anatomy (46).

A national survey of 110 applied anatomy educators by the Mexican Anatomy Society reflected that the clinical anatomy approach was the most common approach used in all branches of anatomy. The most common laboratory activities were dissection (67.6%), the use of imaging studies (64.8%), anatomical drawings (50.7%), and clinical cases (49.3%), showing a prevalence of traditional methods over innovative ones (47).

Although a Chilean university declares dissection irreplaceable, it suggests combining it with technological teaching tools, such as virtual reality, augmented reality, and 3D or 4D virtual simulators, to access dynamic elements that allow the view of difficult-to-access anatomical structures. Consequently, the anatomical knowledge is internalized and meaningful, appealing to student motivation and contributing to improving the educational experience (48).

1.4 Toward research objectives

Posterior to 2006, the number of new admissions of medical students and medical schools increased after the WHO report about the lack of health personnel in 57 countries (49,50), especially in countries with limited resources. The increase in new admissions has caused public medical schools in low- and middle-income countries to face the challenge of providing quality medical training to more students. But with the same number, or even fewer, of qualified teachers, the same budget, and the same amount of teaching resources. As well as limited access to equipment and infrastructure for education (51–58).

Medical education is expensive compared to other higher education studies in terms of facilities and duration (59). In the mainstream literature, the Western world dominates development and scholarship in medical education, underrepresenting information about medical education in the less affluent global south (49).

In affluent countries, medical schools can charge high tuition. For instance, tuition fees in the United States range from USD 16K to USD 70 K per year (60). In less affluent parts of the world, medical education must be organized with a fraction of these resources and often have many more enrolling students than in North American medical

schools, as the need for doctors in these countries is usually high (61) due to the high disease burden.

Given the evolution of science and health education, as well as the new challenges faced by anatomy education, mainly due to the difficulty in obtaining and maintaining cadavers, the reduction in the number of hours, and the educational purpose of instilling meaningful knowledge that can be used in professional practice, we first need to think from a global perspective, about the need to:

- Have an overview of where we are and where we are going in teaching anatomy, according to experts' experience and points of view in medical education.
- Prove the effectiveness of two trending approaches: 1) applied anatomy and 2) the use of technology in anatomy.

The search for and adoption of innovative educational approaches has been reported mainly by authors from developed countries. As Jippes states, the success of implementing curricular changes can be influenced by each country's cultural and economic differences (62) and should be critically adapted to local contexts and culture. Therefore, it is necessary:

- To understand/assess the cultural and economic differences and similarities between countries with high versus low resources and the preferences of their students regarding the teaching of anatomy.

In the medical education literature, there are few reports about studies on anatomical education in low and lower-middle-income countries (LLMIC). In a review of the scientific publications of the specialized journal on this topic (Anatomical Sciences Education) over four years (2020-2023, inclusive), we found that only 3.10% of the 354 articles were published by LLMIC authors. Therefore, it´s necessary to:

- Explore the challenges and implemented strategies by medical schools in low-resource countries.

The little information and scientific production in the literature on medical education in low-resource countries reflect the need for a voice from the global south, not only in anatomy but also in the general education of health professions. A voice that shares with the entire world the adaptations and strategies implemented to guarantee quality anatomical education that contributes to the training of doctors according to the standards demanded by 21st-century society. In addition, it promotes mutual learning and collaboration. This dissertation aims to highlight the disparity between the two worlds, describing the different contexts and focusing on:

- How can anatomy teaching be optimized?

- How do differences between higher-income countries (HIC) and lower-middle-income countries (LMIC) influence anatomy education?
- How do resource-deprived countries in the Global South uphold the anatomy teaching obligation?

1.5 Research questions for a program of studies.

1. The question "*How can anatomy teaching be optimized?" w*as addressed in three studies.

Chapter 2 is a perspective account of the future of anatomy education, partly based on the literature and partly on interviews with selected experts.

Chapter 3 describes a mixed qualitative and quantitative study focused on the question: Does an online anatomy course improve the performance of medical students in a practical examination of gross anatomy?

Chapter 4 compares the perceptions and performance of junior and senior medical students regarding the use of radiological anatomy as an alternative applied anatomy approach.

2. The question, "How can differences in anatomy teaching between low-income and high-income *countries influence anatomy education from the perspective of potential future anatomy teachers?".* It was studied by comparing two exemplary countries.

Chapter 5 describes a study that compares medical students' interest in gross anatomy learning and teaching in Nicaragua and the Netherlands.

3. The question, *How do severely resource-deprived countries in the Global South uphold the anatomy teaching obligation?* It was studied through the literature and by interaction with anatomy teachers globally.

Chapter 6 provides a literature review of approaches to anatomy teaching in seriously resource-deprived countries.

Chapter 7 reports a combined survey and interview study about anatomy education in low-resourced countries. The study investigates how a sample of anatomy teachers across four continents deals with the severe limitations of teaching many students under restricted conditions.

Finally, in Chapter 8, the main research results are interpreted and extrapolated, analyzing their implications and limitations from the author's viewpoint. Based on the analysis of the evolution and challenges of anatomy education, we elaborate on how the teaching of anatomy can be optimized from a global perspective, how the differences between high- and low-income countries influence it, and, finally, how countries with severe scarcity of resources fulfill the obligation to teach it.

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CHAPTER 2

ARE WE FACING THE END OF GROSS ANATOMY TEACHING AS WE HAVE KNOWN IT FOR CENTURIES?

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Author contributions:

Conception of the study:	AYCC, CS, and OtC
Data collection:	AYCC and CS
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Writing the first version of the manuscript:	AYCC
Critical review and adding import intellectual content:	CS, RLAWB, EHFMC, MSvL, OtC

All authors consented to the final version before submission to the journal.

2.1 Abstract

The status of anatomy education in undergraduate medical education has dramatically changed over the past century. From the preclinical program's most critical and time-consuming component, anatomy education has reduced size and status and yielded in curricular space to accommodate other disciplines and topics. Meanwhile, radiology has become more prominent as a means to visualize anatomy, not only in clinical care but also in education. For this perspective paper, the authors, all with backgrounds in anatomy, radiology, and medical education, conducted structured conversations with several academic colleagues with similar backgrounds, reviewed pertinent literature, and analyzed the causes of the historical decline of a knowledge domain of medical education, that nevertheless is widely considered essential for medical students and graduates.

After this analysis, the authors propose four ways forward. These directions include systematic peer teaching and developing anatomy education as a scholarly domain, further vertical integration with postgraduate medical education, full integration with radiology education, and capitalizing on educational technology. Schools in several industrialized countries have made steps in these directions, which can be further strengthened. These steps are less easy to make in less affluent countries and countries with curricula strongly determined by tradition. To respond to changes in global health and health care, combined with the inevitable technological progress and international mobility, we believe all schools will move in these directions, slower or faster.

Keywords: Anatomy education, radiology education, vertical integration, technology, future

2.2 Introduction

Since Vesalius (1514-1564), the founder of accurate anatomy texts and drawings and arguably the father of current anatomy teaching, medical education in universities has strongly emphasized anatomy, if not its core pillar, for centuries. Around the turn of the previous century, two to three years of the preclinical curriculum devoted to morphology (anatomy, histology, and cytology) was considered time well spent, and around 1960, Dutch curricula still contained 225 to 572 hours of anatomy teaching. (1)

Likewise, in 1901, medical schools in the United States had about 549 hours of anatomy teaching, and by 1955, approximately 330 hours (2). The latter half of the 20th century showed a continuous decrease in the absolute and relative time devoted to teaching and learning anatomy in terms of curricular hours and time students spent studying anatomy. While the same century has witnessed many changes in medical curricula, often aligning with Harden's SPICES model (more student-centered, problem-based, integrated, community-based, and systematic) (3), the decrease in time and effort to acquire anatomical content knowledge stands out. In one Dutch curriculum, the absolute time devoted to anatomy (and other basic sciences) decreased by 60% to about 100 hours between 1990 and 2010 (4). In that year, Australian/New Zealand medical schools ranged in total hours of anatomy teaching from as low as 56 to as high as 560 (5). A similar process happened in less affluent countries. In Nicaragua, by 2019, the medical curriculum contained 102 hours of anatomy teaching (6), a reduction of 68% compared to 320 hours 20 years prior.

Not all knowledge, once considered relevant to medicine and patient care, is current. Some knowledge has become irrelevant, outdated, or discovered as incorrect. Regular adaptations in education are thus needed and justified. While new insights and advances in understanding basic and clinical sciences have been continuously added, and clinical training has become more prominent, existing components of the medical curriculum must decrease to make space.

However, the decrease in time and attention to anatomy in medical education sharply contrasts with a universal acknowledgment by practitioners and educators of the importance of anatomical knowledge for physicians (7). Gross anatomy is considered an undisputed core component of the medical curriculum (8). Anatomical knowledge is indispensable for adequate physical examination of patients, irrespective of specialty, but it is also the foundation of the language of medicine. If inter-collegial and interprofessional communication could use the language rooted in the names of anatomical structures, adequate patient care for various health professionals would be possible.

The recent decrease in curricular time for the basic sciences includes domains other than anatomy, but the latter is the focus of our current contribution. Given the continuous decline, medical educators must ask themselves the following questions:

What may have caused the quantitative decline in anatomy teaching? Most importantly, how can adequate quality anatomy teaching be guaranteed in the future?

2.3 What may have caused the quantitative decline in anatomy teaching?

One cause may be the decreased academic status of anatomy in medical schools. Research weighs in on this change of status. Significant anatomical discoveries were made daily in the 19th and early 20th centuries. Anatomical discoveries happened in the second half of the last century (9). However, research diminished modestly, and education became the primary mission of anatomy departments, which consequently decreased in size, funding, and academic staff. Medical graduates with academic research ambitions are now less likely to choose (gross) anatomy as a career unless education is their passion (6,10), resulting in an often-voiced lack of qualified anatomy teachers (11).

A legitimate wish to turn fragmented and disconnected courses in the medical curriculum into a coherent program based on clear objectives derived from patient care may be another cause. Horizontal integration (i.e., the combined educational contributions of various basic sciences) and vertical integration (the integration of clinical subjects with basic science information) have been hallmarks of modern medical curricula (12–14), as well as a legitimate shift from memorization of facts to problem-solving (15). Integration makes the contributions of separate basic sciences less demarcated than discipline-based courses. An unintended consequence of integrated tests is allowing students to pass with relatively low scores for minor parts of these integrated tests (i.e., anatomy). In contrast, anatomical knowledge previously had its tests, which required more knowledge to pass the test (16).

Next, the notion—correct or not—that much of what is learned in medical school is not directly applicable in clinical practice may have fueled discussions in curriculum committees when searching for space to incorporate new elements in educational programs. Depending on the clinical specialties around a committee's table, clinicians may not always acknowledge how much time and effort students need to acquire new (anatomical) knowledge (17). Encapsulated knowledge, once acquired, may become tacit in experienced clinicians (18), causing this underestimation.

Finally, the (again legitimate) push toward more and earlier clinical training in the medical curriculum requires space because curriculum lengths hardly ever increase. This space must be found by decreasing components that seem less relevant. In addition, the substantial costs of anatomy education would be lowered, which may have weighed in with considerations to reduce it.

This multifold background is not a *deliberate* restriction of anatomy education because of its irrelevance; instead, it seems to result from wishes to integrate and include new topics in curricula and lower the space and cost of anatomy education.

2.4 What are the ways forward?

The authors of this opinion article do not intend to judge an acceptable amount of anatomy education and acknowledge a wide variety of anatomy education in medical curricula worldwide. Instead, looking to the future, they propose exploring ways medical education might adapt to ensure that medical graduates and specialists have sufficient anatomical knowledge to provide high-quality and safe patient care.

The status of anatomy education will not return to where it came from. De-integration is not likely to happen (in most schools), and an increase in curricular hours or proportion is not foreseen (in most schools). It is also not expected that gross anatomy will become the central area of research, as reflected in the past. Consequently, the future of anatomy teaching and learning will likely differ fundamentally from the past.

To meet this challenge, multiple conversations with a variety of educators at Utrecht University (notably from anatomy, surgery, radiology, family medicine, and veterinary medicine – see acknowledgments), both directly before the COVID-19 pandemic and two years later, combined with internal discussions among the authors and references to a selection of pertinent literature formed the basis for this opinion piece. We requested informed oral consent from the experts with whom we had the conversations to record the sessions and use the content as inputs for our analysis and discussion. Each author conducted a literature search using electronic databases and virtual libraries of medical education journals; the search terms implemented were anatomy education´s approaches, the future of anatomy education, the continuum in medical education, and integration in anatomy teaching. The analyses and proposals for various perspectives on the way forward do not directly reflect the consulted experts ‘opinion, nor just the literature, but a vision that has matured over the past years. The statements in this perspective article are the authors' informed opinions rather than representing a research report. We offer four ways forward.

1. Systemic near-peer teaching and anatomy education as a scholarly domain

Introducing massive near-peer teaching is the least radical but sound approach that meets the lack of anatomical staff and is a theory-based educational method. A constructivist learning principle is that advanced concepts must connect to an existing knowledge base, which is a reason for the early creation of such a knowledge base of gross anatomy.

While there is nothing wrong with attempts to make learning as joyful as possible, acquiring new knowledge and skills is often, and for many students, only sometimes pleasant. In cases where the return on the investment of a student’s effort occurs only in the longer term, there is a phase of mental plowing that is simply unpleasant, requiring

stamina. Most top musicians and sporters will recognize this. One way to shorten that period is to engage senior students in near-peer teaching for junior students. As teaching assistants, students have been part of anatomy education for a long time. Still, that opportunity is usually reserved for a minority of students as an extra-curricular, often paid activity. In contrast, having *all* students teach anatomy as a mandatory curricular activity for credits would serve several purposes (19). First, it would provide a much faster relevant purpose for applying acquired anatomical knowledge and an antidote against knowledge decay (20,21). Second, teaching, including the preparations for teaching, is considered a highly effective way of learning (22,23). Third, it would enable the organization of small-group education, and faculty members' roles may be limited to guiding peer teachers rather than teaching students directly. Fourth, while many schools recognize the usefulness of teacher training for medical students, only a few have operationalized this (24). Finally, the interest in a teaching career can be stimulated by teaching experience in medical school (25).

This model, applied to clinical reasoning training for junior medical students, has been successfully used at Utrecht University for over 15 years. All final-year medical students undergo compulsory teacher training, including teaching junior medical students. This course is entirely run by students, with just teacher oversight. It is one of the curriculum's most highly valued, practical, and low-cost courses (26, 27). A similar model might work for anatomy teaching and be cost-effective, even if it does not reduce infrastructure costs.

The focus on anatomy as a domain of educational scholarship fits the development of medical education as a scholarly discipline (28–30). Rather than through new anatomical discoveries, the anatomical discipline can distinguish itself in the future through new educational approaches using technology and other means.

2. Vertical integration across the educational continuum

Vertical curriculum integration, often translated as early clinical education in the medical curriculum, also encompasses the teaching and learning of basic sciences during later phases of medical education. The divide between undergraduate preclinical and clinical education has always been the focus of vertical integration (31–33), but the extension to postgraduate training is a logical next step. Medical specialties differ in need of specialized anatomical knowledge. Surgery, radiology, neurology, gynecology, and orthopedics require specialized anatomical knowledge bases, which need not be fully required for family medicine or dermatology. In postgraduate training, focused clinical anatomy education and assessment should secure specialty-specific clinical proficiency. The joint anatomy knowledge base that all medical graduates must master should be enough to enable smooth interaction with any clinical consultant, orally and through writing, and should allow anatomical explanations to patients in primary care

settings, such as needed for shared decision-making, involving discussion of images in an electronic health record.

Vertical integration over a prolonged time, which implies regular repetition, also serves knowledge retention and has been recommended for anatomy education (34) to prevent the loss of basic science knowledge (35,36). Baker has stressed the need to employ clinically qualified anatomy teachers to establish vertical integration, which extends beyond the contribution of radiologists in anatomy teaching, as explained in the next section (34). Mandatory clinical and applied anatomy training, incorporated into residency programs, will be needed to guarantee sufficient and appropriate anatomy knowledge for specialists in surgical disciplines, neurology, and radiology.

3. Integration with radiology education

A more radical approach to teaching the morphology of the human body is to integrate radiology and anatomy education completely.

Classic teaching of gross anatomy has relied heavily on corpses for dissection and prosection. The living body has become translucent with the discovery of X-ray imaging in 1895. Given the rapid speed of development in the past decades of modern medical imaging techniques like Ultrasound, Computed tomography, Magnetic Resonance Imaging, and Nuclear Medicine, the specialty of Radiology, encompassing all these imaging techniques, has now become the discipline to reveal the gross anatomy of the living body. The primary focus of radiology in patient care is to identify, localize, and characterize pathology, but the educational potential of radiology for gross anatomy education is immense. The integration with anatomy teaching is increasing (37,38) as the interpretation of medical imaging has become an agreed-upon skill for all physicians (39). This vertical integration of anatomy and radiology within the medical curriculum prepares for how physicians interact with anatomy in their practice (34). Increasingly, patients can view their radiological images in the patient portals of their hospitals. Explanations will be asked from primary care providers who need to be able to interpret these images to patients; if not as experts, then at least sufficiently. In addition, handheld ultrasound devices are becoming common in primary care practice, and an increasing number of schools acknowledge that using point-of-care ultrasound (POCUS) will be an essential skill for all medical graduates. Chang Chan found that ultrasound imaging is less intuitive for untrained medical students than other radiological images (40). Interpreting POCUS images is complex and requires extensive practice and special skills; the ultrasound's view does not coincide with the mental image one develops along the three orthogonal anatomical planes when studying anatomy. (40) Nevertheless, there is no reason why junior medical students should not start practicing POCUS to acquire anatomical knowledge that reflects the anatomy they will face in later practice. Many medical schools have incorporated POCUS training in a modest sense or with limitations (41,42).

Until half a century ago, first-year medical students in many schools were asked to possess a set of anatomical dissection utensils for gross anatomy, a microscope for histology and cytology, a white coat, and a stethoscope. While the first is no longer the distinctive attributes of a medical student, a tablet computer and a handheld ultrasound device may very well be the attributes of a medical student as they become increasingly affordable.

Multi-dimensional imaging, using volumetric imaging data acquired with CT or MRI, has been extensively applied in radiological anatomy education in the undergraduate medical curriculum of the University Medical Center Utrecht in the Netherlands, both for teaching and student assessment (43). As a result of this development, radiological anatomy has become an essential and likely growing component of anatomy teaching in medical schools.

4. Educational technology and other innovations

Dissection practicums and lectures, as century-old dominant methods of anatomy teaching and training, have been supplemented with several new approaches in the 20th century, including models, body painting, and early computer-assisted instruction methods. The 21st century has witnessed tremendous development in technological approaches to anatomy teaching.

Dynamic three-dimensional (3D) images, with features of rotation, displacement, zooming, changeable transparency, and virtual dissection, are rapidly appearing on the market and in non-commercial provisions (44,45). A recent randomized study revealed that students using 3D models of hand and foot answered more subsequent test questions correctly and needed less time than students who completed the assignment using anatomical atlases alone (46). Augmented reality and virtual reality techniques are also quickly emerging (47), while discussions about their precise nature and use are ongoing (48).

Life-size virtual dissection tables have emerged in the last decade as an option to replace cadavers and allow students to use their fingers as scalpels to dissect virtually. One study showed how teaching with a virtual dissection table, combined with 'live' cadaver CT scans, appeared more beneficial to acquiring anatomical knowledge than traditional radiological anatomy seminars and conventional anatomy training (49). New technologies will include holographic and haptic techniques, often first developed for surgery but, with increased availability and low cost, very well suited for education. The discussion of whether the dissection of cadavers will disappear from medical curricula and be replaced by technology, given the excellent simulation models that have emerged and other technology that will appear on the market, is not one of technology only. Dissection of human cadavers of deceased individuals has a significant ethical component. Dissection has long been considered an initiation rite for medical students (50), and some schools have elaborated this education to pay tribute

to the life of the deceased and the family, regarding the corpse as a 'silent mentor' for the student (51,52).

2.5 Discussion

Anatomy education may be at a crossroads in the history of medical training. Curriculum developers will need to carefully weigh a new position of anatomy education for medical students and residents. As food for thought, our proposed directions include a clear education foundation of anatomical knowledge in a very early phase, primarily conducted as near-peer teaching by more advanced students who learn through teaching, and an integration of anatomy with radiology education in subsequent years. In addition, dedicated postgraduate clinical anatomy education geared to the specialty of interest will likely yield a better learning effect than a concentration of anatomy education in the undergraduate phase.

In all phases, technology will have an important role. With augmented reality, images created and combined with images derived from advanced 3D models will allow for a just-in-time learning process extending across the educational continuum. Not all innovations in anatomy education will be available for low-resourced countries (53). While some schools in the more industrialized world have taken significant steps in these directions, other, more traditional schools that are less involved in curriculum modernization may need help creating such radical steps within a short timeframe.

Although technology could represent a problem in countries with low-income resources, we believe that the determining factor is not economic because even in those countries, primary and easily accessible technological tools are available. The dynamics of curriculum reforms are often disruptive to existing practices, power structures, and educational philosophies (54). In addition, the cultural dimensions that influence the implementation of curriculum innovations in medicine must be considered, which, according to Jippes, are Power Distance (PD), Uncertainty Avoidance (UA), and Individualism/collectivism. Lower-middle resources countries have high PD and UA and low Individualism, which means professors prefer independently to design the courses in their respective disciplines, which also means strong resistance to curriculum innovations (“fear of the unknown”), evasion of undertaking innovations outside organizational norms, and of stimulating championing of new ideas (55).

We consider that the essential thing in teaching anatomy is contributing to the training of doctors capable of responding to the primary health problems in their environments. Part of that training is using our five senses to obtain patient information for proper treatment, adapting to new settings, and continuing learning. Therefore, training students, teachers, and professionals in using technology or devices such as portable ultrasonograms should become one of the core components of anatomy training. It will be a matter of global social responsibility to provide access to

technological innovations to low- and middle-income countries. Furthermore, we believe that with extensive international information exchanges, innovations will likely spread and be picked up much faster than they were decades ago. Therefore, all schools will move in these directions, slower or quicker.

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CHAPTER 3

DOES AN ANATOMY ONLINE COURSE IMPROVE PERFORMANCE OF MEDICAL STUDENT IN A PRACTICAL EXAMINATION IN GROSS ANATOMY?

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Author contributions:

Conception of the study:	AYCC and EHFMC
Data collection:	AYCC
Data analysis:	AYCC, RLAWB, EHFMC, MSvL, OtC
Writing the first version of the manuscript:	AYCC
Critical review and adding import intellectual content:	RLAWB, EHFMC, MSvL, OtC

All authors consented to the final version before submission to the journal.

3.1 Abstract

Aim. An online learning course in anatomy was added to the regular academic anatomy course in the 2nd year of medicine at UNAN-Leon in Nicaragua, using the MOODLE platform. This study aims to determine the learning effect of this course.

Method. Second-year medical students were randomly allocated to an experimental (N=25) and control group (N=50). Only the experimental group had access to the online learning module. We compared the experimental and control groups' performance on regular anatomy assessments and an objective structured practical exam (OSPE). Five focus groups were also interviewed to learn about their experiences with the expanded course.

Results. Of the students in the experimental group, 94.1% and 81.6% of students in the control group took the OSPE. The experimental group significantly outperformed the control group (41.1 ±19.3 points vs. 32.1 ±23.1 points) on the OSPE. No differences between the two groups were found on the regular anatomy examination. Focus group interviews revealed that students ‘opinions about the online course were generally positive.

Conclusion. In general, adding an online course to the regular course was beneficial. The qualitative evaluation results of this intervention provide us with input about how to teach and evaluate the anatomy course and how to improve the online course further to enhance anatomy learning.

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3.3 Introduction

Knowledge of the human body is essential for understanding the relationship between structure and function and how the disease can modify both (pathophysiology). In some instances, it also forms the basis for the physical examination and interpretation of radiological images and therapeutics (1,2). Three instructional formats traditionally teach anatomy: dissection, lectures, and anatomic atlases (3,4). In past decades, the time devoted to anatomy education in medical schools has decreased dramatically across the globe (2,5–9). Dissection even has at many medical schools more or less fallen into disuse as a consequence of curricular reorganizations, high costs, and relatively low efficiency: there is no doubt dissection is effective, but it is also time-consuming and restricted to specific facilities (10–16). However, anatomy teachers and departments have been inventive in finding new ways of teaching to compensate for the loss of curricular time and increase their education's efficiency. While prosected specimens have already been around for a while (5,9,17), in more recent years, other instructional formats were added, e.g., teaching anatomy in the living body, teaching anatomy by radiological imaging (ultrasound, X-ray, CT, and MRI); (18–24), teaching anatomy through physical examination (15,25), as well as more unconventional forms of teaching, such as body painting (26–29), yoga & pilates (30), and plasticine/clay modeling (31–33). However, the scope of these instruction forms is limited, and they can play only a supplementary role in anatomy education.

The most recent trends in anatomy education revolve around the developments of different technological tools; these include computer assistance learning (CAL) (34–37), applications (app) for electronic devices like mobile and tablet (38–41), integration of social media like YouTube and Facebook, into undergraduate learning (5,8,42–46), Learning management system (LMS) like MOODLE (Module Object-Oriented Dynamic Learning Environment) the most known (47–49).

Among the introductory science courses, gross anatomy represents a unique opportunity for incorporating technology and electronic dissemination of information due to its 3-dimensional and layered properties and the visual nature of the course material (21). Online anatomy exercises provide learning opportunities for students outside the lecture room that are of particular value to learners and teachers (50). Apart from this, online learning can also be viewed as an extension of distance learning, which improves access to educational opportunities for learners that do not belong to the traditional groups future physicians and health care workers are recruited from or come from families with limited means (51),

The purpose of the present study was to investigate whether an online gross anatomy course, as a complementary and additional tool, improves students´ knowledge of gross anatomy compared with a traditional anatomy course, which, in our case, consists mainly of lectures, atlases, and prosected specimens. The online gross anatomy course was supported by the MOODLE platform, a facility that is relatively inexpensive and, hence, affordable for medical schools in emerging countries. As the

primary purpose of an anatomy course at a medical school is to teach anatomy effectively, we explicitly did not contrast regular anatomy courses with online courses. There are no plans to abandon the regular course. Still, given its relatively unattractive nature (mostly lectures and learning from books), we expected that adding an online course to the regular course would motivate students and improve their anatomy knowledge. Two groups were formed to investigate this question: an experimental group, which was offered access to an online course, and a control group, which was denied access to this facility. Both groups could attend the regular course and all its facilities; however, in this respect, the control group was not disadvantaged compared to the experimental group. After finishing the course, both groups were compared on two anatomy knowledge assessments: a formative OSPE (Objective Structured Practical Examination) and performance on the regular summative anatomy examinations (oral and practical work). In addition, we explored students' perceptions of the online anatomy course and the OSPE in a qualitative study.

3.4 Method

Design. The study's design was a mixed-methods approach (52,53). The first part involved an experiment in which experimental and control group participants were compared on their OSPE scores and regular anatomy assessments; the second part was a focus group study in which students' views of the online course and the OSPEs were explored.

Context. Regular anatomy teaching in the medical curriculum at UNAN-Leon *(Universidad Nacional Autonoma de Nicaragua, Leon)* in Nicaragua. This medical school's competence-based curriculum adheres to the SPICES principles (Student-centered, Problem-based, Integrated, Community-based, Electives, Systematic) (52). The curriculum is structured in units, with anatomy integrated with other basic sciences from the 2nd to the 5th year. The main educational formats in anatomy are lectures and prosection sessions in practical classes of organ-system-based units, such as the cardiovascular, digestive, respiratory, and reproductive systems.

In the regular anatomy course of the second year of medicine, the different themes are delivered during weeks 1 and 3 in the respiratory unit, weeks 1 to 3 in the cardiovascular unit, and weeks 1 to 4 in the digestive unit. In the respiratory unit, anatomy is included in radiology (X-rays) in the fourth week of the unit.

The regular assessment of anatomy is carried out during the practical class in each of the units, which includes anatomy at three consecutive times: at the beginning of practical class, in the form of a short-written test (with two open theoretical questions) that contribute for 10% in the anatomy assessment, then, in the form of oral small group participation (the results of which contribute for 50% in the assessment), and finally in the form of a short practical oral test (spot examination) which contributes for 40% in the final mark (grade). The scoring of the oral anatomy participation is basically at the teacher's discretion; hence, their reliability cannot be assessed. At the end of each unit, students have to make a final written examination covering the whole unit and include

some questions on the anatomy taught in the course (the results of this final written examination were not included in the study).

The experimental study

Participants. 75 students in their second year of medicine were randomly assigned to form the experimental (25 students) and the control (50 students) groups on each unit. We decided to create a control group twice as large as the experimental group, for the OSPE used to assess anatomy knowledge was voluntary, and students in the control group, in particular, might be disinclined to attend the OSPE. For this reason, the experimental group remained the same throughout the study. In contrast, a new control group was formed each time a new unit started (students could only be control participants once in the study, i.e., new control groups were formed by randomly selecting students who had, until then, not participated in the survey). All students in both groups were between 18 and 20 years old.

The experimental group was divided into four subgroups of 6, 6, 6, and 7 students each. At any point, the four subgroups were in different units (respiratory, cardiovascular, digestive, or primary health care). Students in the Primary Health Care unit could temporarily not participate in the online course because the academic content of this unit does not include anatomy, and students were in health centers outside of the university´s premises. Hence, the experimental group comprised the remaining three subgroups for each unit. As we did not analyze our data at the individual unit level, the small number of participants in each unit is not problematic. Control group students also attended different units, entirely per the regular program.

Experimental procedure. The addition of the online course to the regular course was the experimental intervention. Students in the experimental group had exclusive access to the online course, which allowed them access to the MOODLE platform as "registered users." The experimental and control groups could participate in the regular anatomy course. Participation in the OSPE, for both experimental and control students, was voluntary. In the period covered by our study, most experimental students had the opportunity to participate in 3 OSPEs, each evaluating different topics (cardiovascular, digestive, and respiratory), and most control students participated in at least 1 OSPE while in the control group. The OSPE is a new concept in the practical assessment of basic medical sciences, basically a modified form of an OSCE (Objective Structured Clinical Examination) (53,54). The applied OSPE was voluntary and consisted of 20 stations, which assessed knowledge of gross anatomy and radiological anatomy of the digestive, cardiovascular, and respiratory systems. Students stayed in each station for 1 minute, and anatomy teachers and student assistants of anatomy acted as judges. The OSPEs were held at the end of each unit last week.

The online anatomy course consists of 4 modules. An Introductory module addresses the role of online learning and some general anatomical concepts (anatomical terminology and planimetry) and aims to familiarize the student with the basics of imaging techniques. The other three modules cover the cardiovascular,

respiratory, and digestive organ systems. (See Appendix 1). The MOODLE platform designs and delivers the experimental online anatomy course. MOODLE is a free web application (software) or course management system designed to help educators create learning communities online through virtual courses (e-learning) or using an online space that supports face-to-face modalities (55).

The online course we developed at UNAN-Leon employs five academic activities that MOODLE offers: assignments, academic chat, academic forum, collaborative task (wiki), and questionnaire (test). In assignments, students develop a didactic guide of independent work, which contains exercises to do like elaborate graphic organizers (a visual and graphic display that depicts the relationships between facts, terms, and or ideas within a learning task (56) or complete/write the name of designated anatomical structures. In the academic forum, students are presented with a description of a hypothetical situation (like a problem case), together with one or two questions about anatomy or radiological anatomy; their task is to discuss the case and answer the questions, which in general requires they perform a literature review. In the academic chat, students answer anatomy questions prepared by the tutor, which could be about theoretical or practical issues. This academic chat is the only synchronic activity for which participants must simultaneously be online. In the collaborative task (wiki), students work in small groups on an online paper about anatomy or radiological anatomy. This is the only team activity in the online course. Finally, questionnaires or tests consist of 25 or 30 questions of different types: multiple choice, short answer, association, drag the text into images, and fill-in-the-blanks (missing word). Tests in the online course are exclusively used for formative purposes (self-testing), a significant feature in online learning (57). Appendix 1 presents an overview of the content of the online course.

The experimental and control groups had access to the teachers in the regular anatomy course through teacher consultations.

Independent and Dependent Variables. The independent variable (experimental intervention) was the traditional course plus the online course versus the traditional course only. The dependent variables were scores from four OSPE and four regular anatomy assessments, one for every unit. The scale used in both (OSPE and regular anatomy assessment) was from zero to one hundred, i.e., expressed as percentages of the maximum score that could be obtained.

Analysis. A Mann-Whitney U test (nonparametric) was used to test differences between the experimental and control groups on the regular anatomy assessment and the OSPEs (a p-value <0.05 was considered significant). Cohen´s d was calculated as a measure of effect size.

Qualitative study

Data collection. Five focus groups (one for the experimental group and one for each control group) were conducted at the end of the first year of intervention. We performed one focus group for each control group because of different schedules. In

each focus group, ten students participated voluntarily; they were recruited with the help of the student representative. The focus group sessions lasted, on average, 90 minutes; they were audio-recorded, transcribed, and analyzed using coding and keywords according to the question guides for a focus group. These guide questions contained questions about online courses (opinion about activities, usefulness, reasons for low participation) and OSPE (opinion of the OSPE, usefulness, reasons for the difference in the scores between OSPE and regular assessment) (Appendix 2).

Analytical framework. We used conversation analysis, as this technique considers the context of the site where the research occurred (58) (59). We use the spiral model of Schilling (2006), which organizes the different content analytic procedures into five levels or phases in interpreting the text (60):

1. We converted the recorded audio from the focus groups into raw text data (transcription of each focus group).
2. We converted the raw data into condensed protocols. The principal researcher established the protocols of codifications according to the presence and frequency of the elements.
3. We converted the condensed protocols into a preliminary categorical system and established two topics of analysis (unitizing process): online courses and OSPE.
4. We use the preliminary category system to generate coded protocols. We determined the categories of analysis for each topic.
    - The categories for online course topics were the content of the course, its usefulness, students´ preferences, and participation in the course.
    - For OSPE topics, the categories were the usefulness of the exam, students´ preferences and opinions, and the difference in the scores between OSPE and regular assessment.
5. We analyzed coded protocols to generate interpretations about our topic of interest by making inferences. We extracted explanations explicitly or implicitly in the participants' speech in the focus groups.

Ethical issues

Participation in the study was voluntary. Anonymity, the purpose of the study, and handling of data of both OSPE´s grades and the Focus group´s recording were explained to students. Approval was obtained from the authorities of the Faculty of Medical Sciences.

3.5 Results

Results of the experimental study

Participation in OSPE. Despite the OSPEs not being mandatory, 63% and 94% of the students participated in all four OSPEs during the study. Students in the experimental group were more inclined to take the OSPE than students in the control

group: 94.1% vs. 77.8% in the first OSPE, 78.9% vs. 63.2% in the second, 84.2% vs. 81.6% in the third, and 84.2% vs. 73.7% in the last OSPE.

Comparison of experimental and control groups on OSPE performance. In 4 OSPEs performed, the experimental group scored an average of 41.11% (SD ± 19.32) of the maximum number of points that could be obtained, and in contrast, the control group scored an average of 32.14% (SD ± 23.1). This difference was statistically significant ($p<0.005$), with an effect size of 0.42 (Cohen´s *d*) (Table 1).

Comparison of experimental and control groups on regular anatomy assessments. We found no significant differences in average grades obtained on the regular anatomy assessment between the experimental (mean= 70.31, SD= 11.6) and the control groups (mean=69.62, SD=12.5), expressed on a scale from 0 – 100%. (Table 1).

Table 1 compares scores obtained in practical class and OSPE between experimental and control groups in the four rotations.

	Experimental group			Control group			Sig (p)	Cohen's delta
	N	mean	SD	N	mean	SD		
OSPE scores	63*	41,1	19,3	111*	32,1	23,1	<0.005	0.42
Regular assessment in anatomy	74	70,3	11,6	145	69,6	12,5	NS	Does not apply
Mean scores are percentages of the maximum score.								

***** Most students in the experimental group attended 3 OSPEs; most students in the control groups 1 OSPE

Participation in online activities. The involvement of the experimental group in online activities was 83.3% (N=15/18) during the first rotation, and this declined to 21.1% (N=4/19) during the last rotation. Of the five types of online academic activities, students participated most frequently in the "academic chat" and "test" across the four rotations. The percentage of participation was defined as the number of students who participated in all planned online activities (academic chat and test) relative to the total number of students in the experimental group in each rotation. (Figure 1).

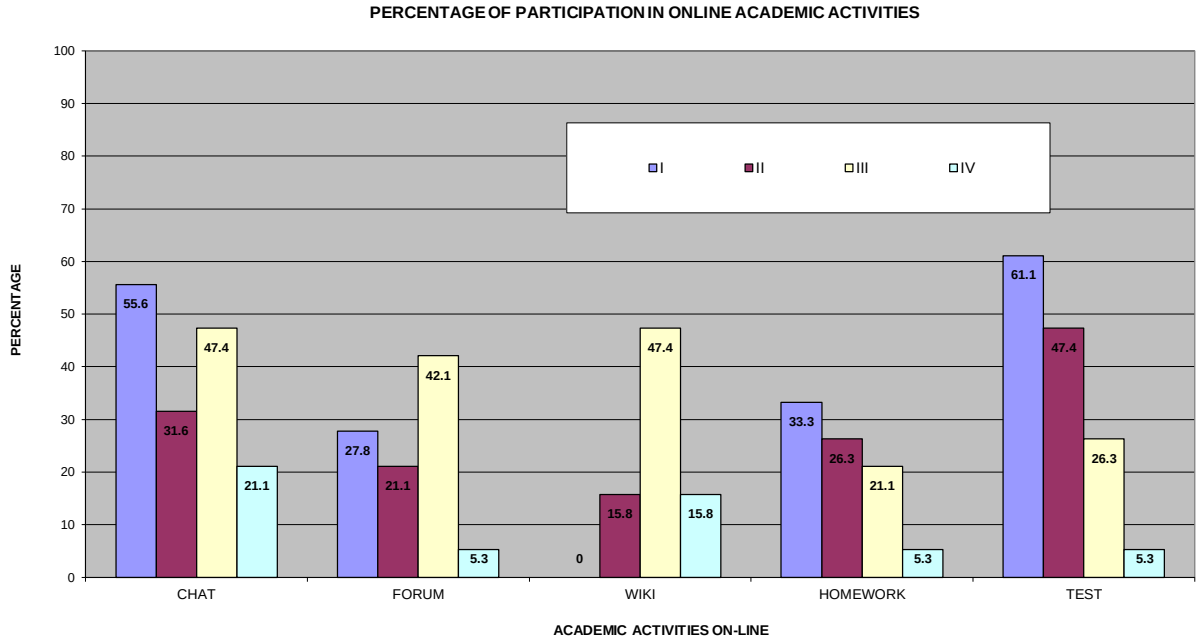

Figure 1. Percentage of participation of the experimental group in online academic activities during the four rotations.
(n=18 (I rotation), n=19 (II-IV rotation); online academic activities: academic chat, academic forum, wiki, homework, and test.)

Results of the Qualitative Study

Five focus groups were held, each with 10 participants. The principal researcher and teaching assistants facilitated the focus groups, recording the sessions and taking notes. All the quotes below are translated literally from Spanish to English, accounting for the grammatical awkward expressions.

Experimental focus group opinion about online activities. Over time, the decreasing use of online facilities was believed to be caused by the absence of a reward (students could not obtain extra points for their curriculum). However, students also said the content of the online course was helpful in their academic training, and it facilitated the study of anatomy. The online activities students liked best were the academic chat and test because, in the chat, they had the opportunity to ask for clarification of issues that were still unclear after the regular anatomy assessment. In addition, the test allowed them to self-assess their knowledge before the regular module´s final examination. (Table 2).

Table 2. Experimental focus group quotations about online activities

Aspect	Students´ quotations
Decreasing the use of online activities is the reason.	- *"One of the main obstacles to the course is that many participants did not take it very seriously, as it is not an activity valued in the medical curriculum."* Other participants agreed on this. - *"The guys' low participation is because they prioritized their class schedules for the mandatory modules of the curriculum over participation in the online course…"*
Content of the online course	- *"It is helping us; it is making the knowledge easier because we are students just starting our careers. The course is helping us to assimilate those things that are difficult for a new student…"* - *"I reinforce the knowledge I learned in class with the online course activities, like the wiki and the personal homework (assignment). This supplements the incomplete knowledge in classes (*face-to-face class*)."* - *"It allowed me to continue studying anatomy because we almost always have an anatomy class at the beginning of the rotation, and in the rest of the rotation, the anatomy is forgotten; we remember it until we go to the exam. While with the online course, we had the opportunity to see a subject of anatomy every week, which served us to continue acquiring new knowledge."*
Online activities students liked best	- *"I liked the chat the most; I liked our participation and interaction because I felt I learned the most from this. I gained knowledge, and I was able to clarify all my doubts. It reinforced my knowledge and clarified the misconceptions I might have had."* - *"The activity that I liked the most was the chat. Although not all students participated, it was good because we all gave opinions. It removed doubts about what I did and did not know. I also liked the test because it measured my skills and how much I had learned and did not know. It even clarified doubts I had about some things."*

Experimental and control groups´ opinions about OSPE. In each focus group, participants said the OSPE was very useful for them because they realized their weaknesses in anatomy, even though they had obtained good grades in regular anatomy assessments. In addition, they said the OSPE should be part of the regular assessment of anatomy because it measures actual anatomical knowledge. They consider the OSPE an objective test because there is only one correct answer (the name of the high-lighted anatomical structure), which, unlike the teacher´s judgment of their participation in practical class, does not depend on subjective judgment. Both groups explained the significant difference between the OSPE scores and the regular anatomy assessments. First, their knowledge remained fresh during regular assessment (2- 7 days after anatomy lectures). At the same time, in OSPE (at the end of the module), they believed they had already forgotten parts of their knowledge. Second, students said they did not study for the OSPE because they could not obtain extra credits. Third, as the regular assessment was an oral examination, students could

try to convince the examiner that their answer to a particular question was correct. The setup of OSPE did not allow for this. (Table 3).

Table 3. Experimental and control groups´ quotations about OSPE

Aspect	Students´ quotations
OSPE usefulness	- *"… and the usefulness it has is that it is quite practical. We arrived at the anatomy lab (regular anatomy assessment) reciting what the book says, and then after the days, we had already forgotten…"* - - *"It´s perfect because it is like a review of the whole rotation, either to consolidate knowledge or to remember better; it would be good if the OSPE were part of the anatomy class."*
OSPE as an objective test	- *"The OSPE is a confrontation of ourselves, either we know or do not know."* - *"We arrived at the anatomy lab (regular anatomy assessment), talked to the evaluator, and maybe we could convince him/her with some words, while in the OSPE, we have to be specific; they ask us if it is or is not."*
Explanations for the difference between OSPE scores and regular anatomy assessments	- *"I consider that the grades differ greatly because we defended ourselves by speaking and invented four crazy things, and maybe the effort was considered. On the other hand, when we did the OSPE, it was learned and acquired knowledge only to analyze, point, and write; it was not to be speaking or using güiri-güiri* (local expression for wordiness)*".* - *"Because we only studied for the moment, we only studied for the lab of anatomy* (regular anatomy assessment)*, after 2 - 3 days, the things we studied, we already had forgotten."* - *"Because for OSPE, we do not prepare because it does not affect us for the final grade of the rotation."*

3.6 Discussion

In this study, we investigate the effect of an additional online course added to traditional teaching in acquiring anatomy knowledge in medical students in their second year at UNAN-Léon in Nicaragua. Moreover, we explored students´ opinions about the online course and their participation in this experiment. We use the OSPE as a measure of knowledge retention. We found that, though participation in the OSPE was voluntary, attendance in both the experimental and control groups was high. The results showed that students who participated in the additional online course performed better on the OSPE than students who did not; expressed in terms of effect size (Cohen´s d), the effect was moderate. Thus, our results do have some practical significance. The qualitative part of the study showed that students found the online course's valuable content in their academic training and said it facilitated the study of anatomy. They found the OSPE very useful because it made them aware of weaknesses in their anatomy knowledge.

Although their OSPE grades are low (on average about 40% of the maximum score), the experimental group performed better in this type of evaluation of

competencies than the control group. In contrast, in terms of performance on the conventional assessment (practical class of anatomy), no effect was found on the online course. This suggests that a practical examination (like OSPE) is more complex than an oral examination (i.e.-, assessment of participation during practical class), an explanation offered by the students in the focus groups. Nevertheless, students in the focus groups identified the OSPE as the most helpful method for the assessment of anatomy knowledge, which is in line with Yaqinuddin, Zafar, Ikram, & Ganguly (2013), who argue that the OSPE is the most efficient tool to assess the practical aspects of anatomical knowledge. Other authors have also recommended OSPEs as the most appropriate instrument to evaluate practical expertise in the medical course (53,61–64). We also believe OSPE scores will improve as we continue implementing and improving the educational research project, and it will become customary for students to attend online courses.

Given that attendance at the OSPEs was voluntary, we were surprised by the large proportion of students in both groups that participated. The slightly more significant proportion of the experimental group that participated could be attributed to the belief among these students that the OSPE was part of the online course. However, even among control group students, the participation was considerable, which suggests they also had a positive attitude towards the OSPE and seized the opportunity to obtain feedback on their learning that the OSPE offered (63, 66, 67).

However, we also observed that participation in online activities declined during the program. The focus group study revealed that this decline in participation in online activities can be attributed to a lack of summative testing and the inability to collect curricular credits. Reward and recognition have been mentioned before as motivating factors for learners to participate in e-learning (65). Students in our focus groups claimed they would be more inclined to join if all anatomy teachers would use online facilities in their regular teaching practice as an integral part of teaching medical sciences. Then, they would become more familiar with this form of learning. Nevertheless, students´ opinions about the online course´s usefulness were generally positive because they felt the course facilitated their learning experience, which aligns with the literature (47,66–68).

Limitations of the study. Our study has some limitations. First, students who have access to the online modules perform better than students who do not, mainly because of extra time investment in their study of anatomy. This would render our results somewhat trivial from a purely experimental point of view (69). We cannot rule out this possibility because we did not investigate the time students spent on anatomy during the study. However, we expect students to balance the time they usually spend during the regular course or in self-study with the additional learning opportunities offered by the online course. From a broader point of view, however, it is the results (durable anatomy knowledge) that matter most, and if students learn more because they invest more time, this would be an asset in providing them with the online course.

Second, we assessed only three organ systems of anatomy teaching (cardiovascular, digestive, and respiratory system) because the corresponding units are included in the second year of the curriculum at UNAN-Leon, where we conducted our

study. However, we have no reason to assume our outcomes will not be generalizable to other domains of anatomy because, even though they were not randomly selected, they involve three of the major organ systems of the human body.

Third, although it was necessary to be registered on the MOODLE platform of UNAN-Leon and have a password for each module, there is the possibility that students in the experimental group have shared information about the online modules or data from their accounts (username and password) with students in the control group. We cannot exclude that this occasionally occurred; however, as the results on the OSPE demonstrate, students in the experimental group significantly outperformed students in the control group. If students in the control group did indeed attend (parts of) the online courses, the actual beneficial effect of the online course would be even more significant than the difference we found in our study.

Finally, an ethical issue was involved in our design because control group students and students who did not participate were deprived of instructional materials they could have benefited from. However, regarding the anatomical content covered, the online course did not contain anything that was not available to the students who were not in the experimental group. Our inability to detect any performance difference between experimental students and the other students on the regular anatomy assessments shows that the latter students were not put at a disadvantage by our experimental design.

Online courses, or e-learning in general, could solve the problems currently facing our medical schools with the traditional approach to teaching anatomy based on dissection and the use of prosected corpses, which are severely limited in availability. These benefits make online courses a complementary teaching-learning strategy for anatomy education, especially in medical schools that cannot offer dissection practice at any scale because of financial and time-investment problems. Even though online courses – or, more generally, e-learning – may incur high costs in the initial (development and implementation) stages, they may be attractive and feasible for resource-deprived medical schools. Once e-learning is available, it probably will save costs in comparison with traditional modes of teaching: both in terms of being less dependent on teachers and on-site facilities, but also because they enable students to attend courses at home, in particular in rural settings, and hence save travel and accommodation expenses (70). Further research is indicated to investigate whether our results can be generalized to other contexts (other medical schools and countries) and disciplines (other than gross anatomy).

Conclusion

The educational intervention's outcomes in its first year of implementation were successful. Students who had access to the e-learning acquired more anatomy knowledge, as assessed by OSPE, than students who did not.

Online learning is an excellent complementary teaching-learning strategy that helps to reinforce, motivate, and ease medical students' learning of gross anatomy. Our

outcomes can be used as a baseline for medical schools in deprived-resource countries considering implementing online courses or other forms of e-learning.

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3.7 Annexes

Appendix 1 Content Per Week Of Online Modules

Week	Cardiovascular	Digestive	Respiratory
1	Heart: internal and external configuration. Pericardium.	Abdominal walls: Muscles of the anterolateral wall, posterior wall muscles, spine (lumbar). Inguinal canal.	Ribcage: diameters, openings, sternum, ribs, spine (thoracic).
2	Mediastinum: classification and content (large vessels). Arteries and veins of the head and neck.	Peritoneum and peritoneal compartments.	Diaphragm muscle and accessory muscles of breathing.
3	Arterial System: Arteries of the abdomen and pelvis.	Oral cavity, salivary glands, and pharynx.	Nasal cavity, paranasal sinuses, and pharynx.
4	Arterial System: Arteries of the upper limb and lower limb.	Esophagus and stomach.	Larynx, trachea, and bronchi.
5	Venous System: Superior Vena Cava and system of azygos veins.	Small intestine and large intestine.	Lungs, pleura, pleural cavity and pleural recesses.
6	Venous System: Inferior Vena Cava and portal vein system.	Liver, biliary tract, and pancreas.	Mediastinum: classification and content.
7	Imagenology of the Cardiovascular System: X-ray PA and lateral thorax.	Imagenology of the digestive system: abdominal plain X-ray and with oral contrast.	Imagenology of the respiratory system: X-ray PA and lateral chest.
8	Imagenology of the Cardiovascular System: thorax CT scan.	Imagenology of the digestive system: Abdomen CT scan.	Imagenology respiratory system: thorax CT scan.
9	Evaluation: online test + OSPE		

Appendix 2 Focus group discussion guide.

Topic	Questions
Online course (only for experimental group)	1. What do you think about the content of the course: activities (forum, chat, wiki, assignment, test) and didactic resources (scientific articles, tutorials, conferences, videos, links)? 2. what did you like the most about the online course, and what did you like the least? 3. What is the usefulness of the online course? 4. Why do you think participation in the course activities was low?
OSPE (for experimental and control groups)	1. About the OSPE, what do you like the most, and what do you like the least? 2. What is the usefulness of this type of evaluation? 3. Is the OSPE an objective assessment? Why? 4. What do you think why is the big difference in the scores between the OSPE and regular anatomy assessment?

CHAPTER 4

RADIOLOGICAL ANATOMY AS AN ALTERNATIVE APPROACH IN ANATOMY TEACHING. PERCEPTION AND PERFORMANCE OF MEDICAL STUDENTS.

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Conception of the study:	AYCC
Data collection:	AYCC, LLMB, EMCR, NOS, DMRA
Data analysis:	AYCC, LLMB, EMCR, NOS, DMRA
Writing the first version of the manuscript:	LLMB, EMCR, NOS, DMRA
Critical review and adding important intellectual content:	AYCC

All authors consented to the final version before submission to the journal.

4.1 Abstract

Introduction. In resource-deprived countries, dissection as a means of teaching anatomy is often not feasible due to the limited availability of bodies, high cost, and safety risks. In Nicaragua, anatomy and radiology education is in an independent format in the medical curriculum.

Objective. This paper explores the impact (performance and perceptions) of using radiological images in teaching anatomy to medical students from a resource-deprived country.

Method. An extracurricular course in radiologic anatomy of the trunk was implemented for third (n=87) and sixth (n=66) year medical students. Pre- and post-tests and a post-course survey were applied. Mean, median, and SD were calculated, with a confidence interval level of 95%.

Results. Perceptions from both groups were similar. Regarding radiological techniques, CT (82.8% junior and 94% senior students) was the most helpful, and ultrasound was the least (49.4% junior and 67.2% senior). Didactic resource acceptance: study guide (73.6% junior and 82.1% senior) and digital-interactive atlas (69% junior and 80.6% senior) got the highest score, while printed books (36.8% junior and 59.7% senior) got the lowest score. The pre-test scores were similar in both groups (the mean of correct answers was 7.98 junior and 8.22 senior). The mean of correct answers increased in both groups in the post-test: 32.03 for junior and 32.82 for senior students (p=0.000).

Conclusions. Integration of radiology and anatomy positively impacts medical students; it should be implemented through a self-directed learning approach and considered complementary in the medical curriculum as a good alternative for teaching anatomy in countries where dissection is not feasible.

4.2 Introduction

Dissection has been the primary anatomy teaching approach for a long time; its didactic benefits are well known, i.e., understanding the 3-D of the human body and developing haptic skills. Nevertheless, due to its limited availability, high cost, and safety risk, this method is operationally, technically, and economically unfeasible for resource-deprived countries (1).

Among the biomedical science courses, gross anatomy represents a unique opportunity to incorporate new information and communication technologies because of its visual nature (1, 2). Various radiological images, such as X-rays, ultrasound (USG), computer tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET), provide information regarding the morphology, function, and metabolism of the human body (3).

The benefits of management implementing X-ray, USG, CT, and MR imaging in studying anatomy in medical schools have been well-reported in recent years. Among the benefits reported are a three-dimensional exploration of anatomical relationships, in vivo visualization of morpho-functional, manipulation of images for a detailed study of specific organs, and ease in interpreting these images in clinical practice (4-15). After cadaver radiography was implemented as a tool in anatomy teaching, the complementary use of radiology in anatomy education has grown. Due to their digitization, greater access to images supports this; consequently, X-ray, CT, USG, and MRI images are now a common platform for learning anatomy in medical schools (2).

Although medical students do not become radiologists, regardless of the type of health care they provide in the future (be it primary or specialized care), they need to develop fundamental knowledge in interpreting radiological images to understand the consultation reports of radiologists (16).

Regardless of their preferred medical specialty, medical students must develop the correct interpretation of imaging and get familiar with the data presented; this skill will help them overcome potential deficiencies in their future clinical practices (17).

Integrating radiological images in anatomy teaching is beneficial because, besides stimulating and reinforcing anatomy and its understanding and clinical application, this synergy leads to better retention of both disciplines (anatomy and radiology) (17).

Curricula integrating medical imaging with dissection/prosection and online multimedia materials have improved students' performance and interest in anatomy and radiology (18).

In Nicaragua, anatomy education in most medical schools is provided through lectures and practical classes, using prosection, models, textbooks, and banners. Radiology education is traditional, involving lectures and mainly using X-ray films. Because of economic cost, access to other radiological imaging methods, like USG, TC, or MRI, is limited. Currently, in Nicaragua, anatomy and radiology education are

addressed independently. Local outcomes from surveys, OSCE (objective structured clinical exam), and OSPE (objective structured practical exam), implemented as part of the regular assessment at the end of academic courses of anatomy and medical skills components, have reflected student difficulties regarding interpreting imaging and correlating anatomical regions due to lack of appropriate cadavers for teaching.

This paper explores the impact of imaging (performance and perceptions) on teaching anatomy to medical students from countries with deprived resources. We investigated the effectiveness of radiological anatomy in anatomy teaching, comparing junior and senior students' performance in pre-test and post-tests and collecting their opinions about the usefulness of imaging through a survey. We expected senior students to perform better and have more positive perceptions than junior students because of their years of experience in medical training.

4.3 Method

Study design

The study design was a quantitative research approach, specifically a group comparison cross-sectional survey design (19).

Context

An extracurricular and accessible course on the radiological anatomy of the trunk was designed and elaborated by the primary researcher and her assistant students using a range of didactic resources.

The course was face-to-face with a methodology that promoted active and collaborative learning through the following didactic activities: lectures, practical classes, and plenary sessions. It lasted six weeks, and the student spent approximately 5 hours a week. Participants had online access to teaching resources (atlases, videos, study guides, and conference presentations).

Didactic videos on anatomy and radiological anatomy and dynamic interactive electronic atlases (using X-ray, USG, and CT images without pathology) were made. The interactive atlas has the following features: descriptive text, a label of anatomical structures, change of view (window), measure tools, image transformation (rotation, zoom), a search button, and mobility through directional arrows.

Another didactic resource was the practical class guide, which contained a checklist of anatomical structures the students had to identify in the atlas. The radiological images used were supplied by the University Medical Center of Utrecht (UMCU) in DICOM format.

We applied the same practical exam of 50 questions before and after the course (pre and post-test study). The practical exam contained three questions about generalities of anatomy, seven questions about generalizations of medical imaging, and 40 questions about the terminology of anatomical structures. Also, we applied a survey

at the end of the course that addressed the following aspects: usefulness of the imaging technique (X-ray, USG, CT, MRI), usefulness and quality of the didactic resources (atlas, knowledge-based videos, printed books, study guides and films of radiological images), and usefulness and quality of each interactive atlas's feature (descriptive text, label, window, measure tools, image transformation, search button, directional arrows).

The team research elaborated on survey and test questions, which the staff teachers then validated.

Sample

Our sample was medical students at the National Autonomous University of Leon, Nicaragua (UNAN-Leon), who participated voluntarily in the trunk's extracurricular course of radiologic anatomy. Students from the third (216 students) and sixth (159 students) year of medicine were invited to participate in the class.

Third-year students (junior) have studied the anatomy of the digestive, respiratory, and cardiovascular systems, which they learned during the second year of their career. However, they have little or no experience with radiological images. Sixth-year students (seniors) have completed their studies about all anatomy systems and are more familiar with radiological images (especially X-rays) because of their clinical practice.

Analysis

The respective academic year was crossed with the variables studied (number of correct answers, perceptions about usefulness, and quality of the didactic resources). Also, we compared the outcomes of the pre-and post-tests of both groups (senior and junior students).

Through a linear regression, Pearson's chi-square test was used for the dichotomous variables and the independent sample' t-student test for continuous variables, considering a value of $p < 0.005$. Mean, median, standard deviation (SD), and p-value were calculated, with a confidence interval level of 95%.

Ethical considerations

Informed consent from participants was requested, and it was explained that their participation in the study was completely voluntary and anonymous. The faculty of medical sciences of the National Autonomous University of Leon, Nicaragua, approved this study.

4.4 Results

A total of 154 students participated in the study: 87 (56.4 %) students in the third year and 67 (43.5%) students in the sixth year of medicine. The predominant age range was 20 – 25 (60.4%), and most students were female (51.9%).

Comparison of performance in pre-test and post-test of both third and sixth-year med students

Both groups' performance (number of correct answers) was very similar. In the pre-test (50 questions in total), both groups got the same minimum (2 correct answers) and almost the same maximum (18 correct answers for the third year and 17 correct answers for the sixth year). The mean was very similar, 7.98 for the third year and 8.22 for the sixth year.

In the post-test (50 questions in total) in both groups, there was an improvement in the test results: the minimum was 12 correct answers for the third year and 20 for the sixth year, and the maximum was 45 correct answers for the third year and 47 for the sixth year. The mean also increased in both groups: 32.03 for the third year and 32.82 for the sixth year. There was statistical significance in both groups, third and sixth year ($p \leq 0.005$). (Table 1).

Table 1. Comparison of performance (correct answers) in pre-and post-test. Pearson´s chi-squared test.

	Third-year		Sixth year	
	Pre-test	Post-test	Pre-test	Post-test
	n=87		n=67	
Minimal	2	12	2	20
Maximum	18	45	17	47
Mean	7.98	32.03	8.22	32.82
Standard deviation	3.94	6.12	3.21	5.77
p	0.000		0.000	

Perceptions of students about the usefulness of diverse didactic resources used during a radiologic anatomy course.

To measure the usefulness of diverse didactic resources in anatomy teaching, we request students to rate on a scale from 1 to 5 points, with 1 being the lowest score and five being the highest. Concerning the use of radiological imaging in anatomy teaching, the four methods (X-ray, USG, CT, and MRI), in general, received a high frequency of 5 points. Students in both groups (third and sixth year) considered that CT (82.8% for the third year and 94% for the sixth year) and X-ray (66.7% for the third year and 77.6% for the third year) are very useful in anatomy teaching. The technique that obtained the lowest score in both groups was ultrasound (49.4% for the third year and 67.2% for the sixth year). The four methods received a higher valuation from the sixth-year group than the third-year group, with a difference between the two appraisals from 8% to 19% (table 2).

Table 2. Frequency of highest score (5) of the usefulness of radiological imaging in anatomy teaching

Radiological technique	Third-year n=87		Sixth year n=67	
	Frequency	Percentage	Frequency	Percentage
X-ray	58	66.7%	52	77.6%
Ultrasound	43	49.4%	45	67.2%
CT	72	82.8%	63	94%
MRI	47	54%	47	70.1%

Regarding the usefulness of different didactic resources used during radiological anatomy, both groups scored high on the study guide (73.6% for the third year and 82.1% for the sixth year) and the digital interactive atlas (69% for the third year and 80.6% for the sixth year). It should be noted that printed books obtained a low frequency of usage in both groups (36.8% for the third year and 59.7% for the sixth year). All didactic resources received higher scores from the sixth-year group than the third-year group, with a difference between the two valuations from 9% to 24% (table 3).

Table 3. Frequency of highest score (5) of the usefulness of didactic resources

Didactic resources	Third-year n=87		Sixth year n=67	
	Frequency	Percentage	Frequency	Percentage
Digital interactive atlas	60	69%	54	(80.6%)
Didactic videos	48	55.2%	49	(73.1%)
Study guide	64	73.6%	55	(82.1%)
Printed books	32	36.8%	40	(59.7%)
Film of radiological images	38	43.7%	45	(67.2%)

All the components had high scores in both groups (third and sixth year) about the features of the digital interactive atlases of radiological anatomy. But the highest score was for a change of view/window (95.5% for the sixth year and 86.2% for the third year), structure search button (95.5% for the sixth year and 88.5% for the third year), and directional arrows (95.6% for the sixth year and 82.8% for the third year). The feature with the lowest score in both groups was the measure tools (59.8% for the third year and 71.6% for the sixth year). It is worth noting that the sixth-year group gave higher scores in all features than the third-year group, with a difference between the two appreciations from 8 to 22%; however, there was no statistical significance ($p \geq 0.005$) (table 4).

Table 4. Frequency of the highest score (5) of the usefulness of the features of the Interactive digital atlases of radiological anatomy

Interactive atlas features	Third-year n=87		Sixth year n=67		p
	Frequency	Percentage	Frequency	Percentage	
Descriptive text	53	60.9%	57	85.1%	0.007
Label of anatomical structures	56	64.4%	52	77.6%	0.280
Change of view (window)	75	86.2%	64	95.5%	0.115
Transformation of images (rotation, zoom)	55	63.2%	53	79.1%	0.111
Measure tools	52	59.8%	48	71.6%	0.541
Structure search button	77	88.5%	64	95.5%	0.209
Directional arrows	72	82.8%	64	95.5%	0.085

The course of radiological anatomy in the medical curriculum

In our study area (UNAN-Leon), radiologic anatomy teaching has not been implemented. Regarding the learning of radiological anatomy courses in the medical curriculum, the majority stated that it should be compulsory (56.3% for the third year and 77.6% for the sixth year), although a good percentage (31%) of the third-year group referred that it should be elective ($p \leq 0.005$) (table 5).

Table 5. Opinions of med students on how radiological anatomy courses should be delivered concerning the curriculum of medicine

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Type of course	Third-year n=87		Sixth year N=67	
	Frequency	Percentage	Frequency	Percentage
Compulsory	49	56.3%	52	77.6%
Elective	27	31%	9	13.4%
Extracurricular	7	8%	1	1.5%
Lost data	4	4.6%	5	7.5%
p	0.004			

4.5 Discussion

This study explored the impact of an extracurricular course in radiological anatomy on third- (junior) and sixth- (senior) year medical students. We investigated in which group (junior or senior) of students the use of imaging for learning anatomy had greater effectiveness by comparing their performance in the pre and post-test and evaluating their opinions about the usefulness of the variables (imaging methods, didactic resources, and atlas's features). The main results were that the performance of both groups was very similar, and senior and junior students improved their output from the pre- to post-test. Opinions about the usefulness were positive in both groups. Senior students gave a higher benefit score in all variables than junior students.

Senior students, in general, scored higher than junior students on the usefulness of the different radiological techniques, teaching resources, and characteristics of the interactive digital atlas. The authors believe this difference in more positive opinions in final year students is because they have more insight into the complex dimensions of patient care (20). In addition, their learning experience during their clinical practices gives them a more positive and practical perception than junior students of achieving new knowledge and skills that may be useful both for their learning and the comprehensive care of their future patients. It confirms that results and activities help students develop practical skills and a positive mind during medical training (21).

Regarding imaging techniques used in anatomy teaching, our findings coincide with the literature's findings, reflecting that CT and X-ray scores were higher than MRI and ultrasound (8, 22-24). Computer tomography (CT) images provide a three-dimensional body view, help understand topographical relations, and improve comprehension of complex anatomical regions (14,17). In addition, students develop observation skills when they observe the CT scan and try to identify anatomical details. This observation skill is considered the key to long-term retention (25). Ultrasound obtained the lowest score among the radiological techniques. We believe this is because identifying anatomical structures and their interpretation is more complicated. After all, ultrasound's view does not coincide with the mental image that one develops anatomical planes when studying anatomy. Therefore, we believe its use in anatomy teaching is not the most optimal.

Students rated the study guide as the most useful didactic resource, confirming its value as an aid to learning, which coincides with what is reported in the literature (26-30). Laidlaw & Harden (1990) define the study guide as "an aid, usually in printed notes, designed to assist students with learning. It indicates what should be learned, how it can be learned, and how students can recognize if they have learned it" (31). The AMEE guide number 16 (1999) categorized the benefits of a study guide into three groups: one, the management of student's learning; two, the provision of a focus for students' activities related to education; and three, providing information on the subject or topic (32).

Junior and senior students rated the study guides and the interactive digital atlas as the most helpful didactic resources, suggesting their preferred active and self-directed learning over traditional teaching methods (33). Since the participants could access the interactive study guides and atlases online, they could work at their own pace in their homes, repeat the exercises, and emphasize the aspects they considered essential or more difficult. It reinforces the benefit reported by the literature about computer-aided learning: the availability of instructional material anytime and anywhere (34, 35). The accessibility of study material and instructions to learn anatomy through images are vital points that encourage self-directed learning and motivate students (25). The importance of self-directed learning in higher education is that it provides the

student with the competence to be responsible for the quality of their knowledge, applying self-determination to learn what they see as imperative for them. It constitutes learning that links life with education (36). These indicate the importance of emphasizing the students' learning process (how they learn) instead of a list of content to fulfill (what they know). Our finding reinforces the importance of self-directed learning (students as the architects of their education and knowledge) and the teacher's facilitating role.

The digital atlas with the highest score features were the change of view (window), structure search button, directional arrows, and scroll. These tools help explore and recognize the anatomical region to obtain an overview, reinforcing the application of radiological images in anatomy teaching to understand complex anatomical parts (6,17).

Years of experience in medical training seem to influence neither performance nor perception concerning implementing the radiological anatomy course since junior and senior groups obtained similar scores. Post-test scores improved compared to pre-test for juniors and seniors, reflecting learning effectiveness.

The finding that students think the radiology anatomy course should be compulsory reflects that they know this knowledge's lack of medical training and the need to integrate radiology and anatomy at any level (preclinical or clinical years) of the undergraduate medical program. Perhaps the most influencing factor was interest and the didactic approach used. The imaging interpretation is not based on row memory but requires logical thinking and reasoning. Therefore, incorporating the integration of anatomy and radiology into the medical curriculum would increase students' confidence in developing clinical skills and promote their motivation (25). It should have implications for the planning of vertical integration and curriculum design.

Limitations of the study

Students who participated were volunteers and, therefore, interested in learning radiological anatomy. This interest may positively influence their opinions and performance. It would be interesting to implement this course in students not interested in radiologic anatomy and explore whether their performance and opinions are positive or negative.

In addition, as the post-test was applied at the end of the course and only for research purposes, we cannot assure that the approach and resources used in this study promote knowledge retention. Further studies should evaluate the long-term impact of this approach and these resources.

Conclusions

The integration of radiology in the teaching of anatomy positively impacts the perception and performance of medical students in both the preclinical and clinical

years. We recommend that this integration be implemented through a self-directed learning approach, using CAL (computer-aided learning) and that complementary teaching methods in the medical curriculum be considered a good alternative for anatomy education in countries where dissection is not feasible**.**

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4.7 Annexes

Appendix

National Autonomous University of Nicaragua, UNAN-Leon
Faculty of Medical Sciences
Department of Morphological Sciences
First unique course: Dynamic Radiological Anatomy of the Trunk

Questionnaire

Dear participant, This is a survey of some aspects of the course that just ended. We request you be sincere in your answers to help us improve the design and implementation. The data obtained will be handled with scientific rigor, and no one outside the course coordinator and her assistants will have access to these data.

I. General data:

Gender	M		F	

Age:	15-19		20-25		≥26	

Current academic year	I	II	III	IV	V	VI	Graduate

II Appreciation of the usefulness and quality

Value the usefulness and quality of the different aspects of the course, considering that 1 signifies the lowest appreciation and 5 signifies the highest appreciation.

1. Didactic tools:

Interactive radiological anatomy atlas with descriptive text and structures´ name labels					
Usefulness	1	2	3	4	5
Quality	1	2	3	4	5
Didactic videos of anatomy and radiological anatomy					
Usefulness	1	2	3	4	5
Quality	1	2	3	4	5

Study guide					
Usefulness	1	2	3	4	5
Quality	1	2	3	4	5

Printed books					
Usefulness	1	2	3	4	5
Quality	1	2	3	4	5

Film of radiological images

Usefulness	1	2	3	4	5
Quality	1	2	3	4	5

2. Value the usefulness of the radiological methods in anatomy teaching

X-ray				
1	2	3	4	5

Ultrasound				
1	2	3	4	5

CT				
1	2	3	4	5

MRI				
1	2	3	4	5

3. Value the usefulness of the features of the interactive digital atlases of radiological anatomy

Descriptive text				
1	2	3	4	5

Label of anatomical structures				
1	2	3	4	5

Change of view (window)				
1	2	3	4	5

Transformation of images (rotation, zoom)				
1	2	3	4	5

Measure tools				
1	2	3	4	5

Structure search button				
1	2	3	4	5

Directional arrows				
1	2	3	4	5

Thank you for your collaboration.

CHAPTER 5

COMPARING MEDICAL STUDENT INTEREST IN BASIC SCIENCES ACROSS DIFFERENT CULTURES: THE CASE OF ANATOMY LEARNING AND TEACHING

This chapter has appeared as follows:

Chang Chan AYC, ten Cate O, Wammes E, Custers E, van Leeuwen MS; Bleys R. Comparing Medical Student Interest In Gross Anatomy Learning and Teaching Across Different Cultures. Journal of Medical Education and Training 2020; 4:050

Author contributions:

Conception of the study:	AYCC, RLAWB and OtC
Data collection:	AYCC and EW
Data analysis:	AYCC, EW, RLAWB, EHFMC, MSvL, OtC
Writing the first version of the manuscript:	AYCC and EW
Critical review and adding import intellectual content:	RLAWB, EHFMC, MSvL, OtC

All authors consented to the final version before submission to the journal.

5.1 Abstract

Objective. Despite the universal significance of anatomy education for doctors, there are vast differences in the quantity and nature of anatomy training among cultures and countries. We investigated how Nicaraguan and Dutch medical students perceive and value anatomy education.

Material and Methods. Junior and senior medical students from a Nicaraguan and a Dutch university were surveyed with questions about their perception of anatomy education, their preference for teaching methods, and their perspective on learning and teaching anatomy. Each variable was cross-referenced with the academic year of training. Outcomes were compared across universities; a p-value was calculated.

Results. The response rate from Nicaragua was 74% (n=301), and from the Netherlands was 35% (n=215). All students agreed that the quantity of anatomy in their curriculum was satisfactory. Most Nicaraguan students were neutral regarding their appreciation of studying anatomy, while Dutch students generally had a high appreciation. Most Dutch students found the quality of anatomy education satisfactory, while most Nicaraguan students thought anatomy education could improve. Senior students preferred dissection/prosection as an anatomy teaching method, while juniors preferred surgery observation. Few students considered becoming an anatomist as a career.

Conclusion. Dutch students appreciated anatomy education more than Nicaraguan students. All agreed that anatomy is essential but not an exciting career option. Students ´differences in perception seem, at least partly, caused by culture and linked to affluence.

Abbreviations

GDP: Gross Domestic Product.; PD: Power Distance.; PY2: Program Year 2.; PY6: Program Year 6.; PY1: Program Year 1. ;PY5: Program Year 5.; SD: Standard Deviation.; UA: Uncertainty Avoidance.; UMC-Utrecht: University Medical Center of Utrecht.; UNAN-Leon: From Spanish Universidad Nacional Autonoma de Nicaragua, Leon.; USG: Ultrasonogram

5.2 Introduction

Human anatomy is one of the oldest disciplines in medicine, has been the foundation for the development of medical knowledge, and has been one of the fundamental pillars of medical training for centuries (1). The study of gross anatomy provides not only necessary morphology knowledge but also an opportunity for reflection on the intrinsic values of life and death and creates empathy for future patients, i.e., it teaches the value of human life (2) and helps to understand body functions and how both structure and function are modified by disease (3).

Anatomists and students have regularly been surveyed regarding their views on anatomy education, focusing on applying their basic anatomical knowledge within the clinical setting (4).

Students entering medical school generally believe that anatomy and working with human cadavers are essential to becoming doctors (4,5). One study among medical graduates in the United Kingdom reported that over half of them estimated using more than 70% of the anatomical knowledge they had been taught during a year of medical practice (6).

Some students reportedly find their preclinical curriculum overloaded and do not experience a culture that values anatomical knowledge, and therefore suggest reducing or even abandoning anatomy from the program (7–9).

In an earlier study, we identified fourteen different anatomy teaching methods, some of which can be useful for less affluent countries (10). Given (a) the current state of anatomy education, (b) the differences between high and low-resourced countries in approaches to anatomy education, (c) the continued importance of anatomy education in medical schools in general, and (d) the reliance on anatomy education on teaching assistance by more advanced medical students and junior doctors (11,12), a comparative study to investigate the interest among the current generation of medical students in anatomy education and in (assisting in) teaching anatomy is warranted. To our knowledge, no international comparative studies have addressed the perceptions and preferences of medical students from two completely different countries and cultures regarding anatomy education.

To understand the differences in national culture and resources between both populations (Nicaraguan and Dutch), we categorized cultures in dimensions (13) and Gross domestic product (GDP) to characterize the difference between the affluent country and the resource-deprived country.

Of the six dimensions of Hofstede´s model (13), those that likely influence curriculum implementation in medical schools are Power Distance (PD), Uncertainty Avoidance (UA), and *Individualism/collectivism* (IC) (14).

Power distance relates to the different solutions to the fundamental problem of human inequality (15,16). In schools with strong PD, professors may independently

design courses for their respective disciplines (17). Uncertainty avoidance relates to the stress level in a society in the face of an unknown future (13,16,18). Medical schools in countries with high levels of uncertainty avoidance should expect to overcome strong resistance to curriculum reform. “Fear of the unknown” may hamper curriculum innovation in countries with strong UA (17). Individualism/collectivism relates to the integration of individuals into primary groups (13,16). Individualist societies prefer undertaking innovations outside organizational norms and stimulate the championing of new ideas. Strong collectivism has been shown to correlate with a low national GDP (17).

Hofstede did not apply his model to Nicaragua but to three other countries in Central America that are culturally similar (Costa Rica, Guatemala, and El Salvador).

Our investigation compares students' attitudes towards anatomy in two large universities in the Netherlands and Nicaragua. We were interested in understanding the differences and similarities in preferences for anatomy education between Nicaraguan and Dutch medical students, as well as their cultural and economic differences. We included junior and senior medical students from both universities and aimed to understand the motivation for anatomy education across medical school years.

5.3 Methods

Setting

The study was conducted in Nicaragua and the Netherlands. The cultural dimensions of the Nicaraguan and Dutch populations are opposite in Hofstede´s indexes (we used the median values of Costa Rica, Guatemala, and El Salvador for Nicaragua): The Netherlands has been calculated to have scores of 38 for PD, 53 for UA, and 80 for IC, while their average values in Central America are 65 for PD, 94 for UA, and 13 for IC (17).

There also are differences in resources. According to the World Bank, the GPD in The Netherlands averaged 348.1 billion US dollars between 1960 and 2017 and was 826.2 billion in 2017, representing 1.33% of the world economy (19). Nicaragua´s GBP was worth 13.81 billion US dollars in 2017 (averaging 4.02 USD billion between 1960 and 2017), representing 0.02 percent of the world economy (20).

The Faculty of Medical Sciences of the National Autonomous University of Leon, Nicaragua (UNAN—Leon) is a state-funded public University founded in 1812. The University Medical Center (UMC-Utrecht), affiliated with Utrecht University in the Netherlands, was founded in 1636. Both schools have a modern, objective-based curricular model organized in cyclical modules or blocks (21).

Anatomy education in UNAN-Leon is delivered to the students throughout the undergraduate training through 12 mandatory modules during the second, third, and fifth years of Medicine. Medical students receive 102 hours of anatomy teaching (46

hours of lectures and 56 hours of practical classes, including demonstrations with prosected specimens and plastic models). There are no elective anatomy modules in the curriculum. If the department has enough cadavers, elective dissection courses are offered, and if the students request a radiological anatomy course, the anatomy department provides it.

At UMC-Utrecht, anatomy is taught in years 1 – 5 through 21 mandatory modules with 145 hours of anatomy teaching (40 hours of lectures, 8 hours of seminars, 13.5 hours of small group teaching, 70.5 hours of practical sessions, and 13 hours of meet the expert sessions). In year two, students can choose two elective courses of 5 weeks each. In years 4-5, students must choose two elective courses of 4 – 6 weeks, and 30% take an anatomy course, selecting a region to dissect and study (thorax, abdomen, pelvis, extremities, head and neck, or central nervous system).

Population

We collected the opinions of junior and senior medical students in both medical schools to evaluate the development of interest in anatomy teaching over time.

In UNAN-Leon, 404 medical students were eligible to be included: 245 students from the second year and 159 students from the sixth year, and in UMC Utrecht, 842 medical students, 307 from the first year, and 535 from the fifth year of Medicine.

Sampling

For four months, second- and sixth-year medical students at UNAN-Leon and first- and fifth-year medical students at UMC-Utrecht were asked to complete an anatomy education questionnaire (Appendix 1). We selected different academic years, considering the first and last years of Medicine. In UNAN-Leon, the first year is typical for all careers; therefore, second-year students were selected as juniors.

At UMC-Utrecht, students filled out the questionnaire through the online tool Survey Monkey®. Students received an email with the instructions and the link to the questionnaire. At UNAN-Leon, students filled out a paper version of the same questionnaire, for which junior students were approached at the beginning of a practical anatomy class. Senior students were approached with the help of student representatives to fill out the questionnaire during their free time.

Questionnaire

A questionnaire was applied, which contained biographical items about gender and age and Lickert scale items about students' perceptions. The items related to perceptions were: appreciation for anatomy as a topic in the medical curriculum, the importance of anatomy for becoming a doctor, the quantity and quality of anatomy education in their curriculum, interest in becoming an anatomy teaching assistant and/or a professional anatomist, most exciting aspect of anatomy and perceived

effectiveness of different teaching methods. The other teaching methods correspond to a list that was used in a previous study about approaches to anatomy teaching (10): lecture, dissection, prosection, physical examination, body painting, demonstration plastic model, active clay/plasticine modeling, radiology images, USG devices, surgery teaching, self-directed e-learning, e-learning with online and peer support, yoga/pilates.

To evaluate the questionnaire for improvement or adjustment, we first conducted a pilot study to validate the survey, with six students (3 juniors and three seniors) at UNAN-Leon and three junior students at UMC-Utrecht.

Analysis

The academic years were compared with each of the variables studied. Subsequently, these results were compared among the universities participating in the study. Means and t-tests were calculated.

Ethical Issues

Participation in the study was voluntary. The anonymity, purpose, and handling of data from the survey were explained to students. In UNAN-Leon, approval was obtained from the Faculty of Medical Sciences authorities. In UMC Utrecht, approval was obtained from the Netherlands Association for Medical Education Ethical Review Board.

5.4 Results

Population

A total of 516 senior and junior medical students from two different Universities (Nicaraguan and Dutch) participated: 214 (87%) second-year (program year 2, PY2) and 87 (55%) PY6 students from UNAN-Leon, 76 (25%) PY1 and 139 (26%) PY5 students from UMC-Utrecht. In both universities, anatomy teaching assistant students were excluded.

In 3 of the four groups, most participants were female: 76% of PGY1 and 74% of PY5 in UMC-Utrecht and 70% of PY6 in UNAN-Leon. Only in UNAN-Leon, most PY2 participants were male (57%). The age distribution was similar in UMCU-Utrecht (87% of PY5 students 20-24 and 77% of PGY1 students below 20) and UNAN-Leon (94% of senior students 20 – 24 and 71% of PGY2 students below 20).

Questionnaire results

Most junior students from both universities did acknowledge that anatomy is of utmost importance, 69.1% for UNAN-Leon and 90.7% for UMC-Utrecht ($p = 0.004$ and $p = 0.000$, respectively). Most of both UMC-Utrecht groups classified anatomy as a positive topic in the medical curriculum (“more than most other topics”), 66.4% for junior

students and 80.2% for seniors; p = 0.000. At UNAN-Leon, the scores were lower for both groups, 19.5% for juniors and 29.9% for seniors (p =0.007) (Figure 1).

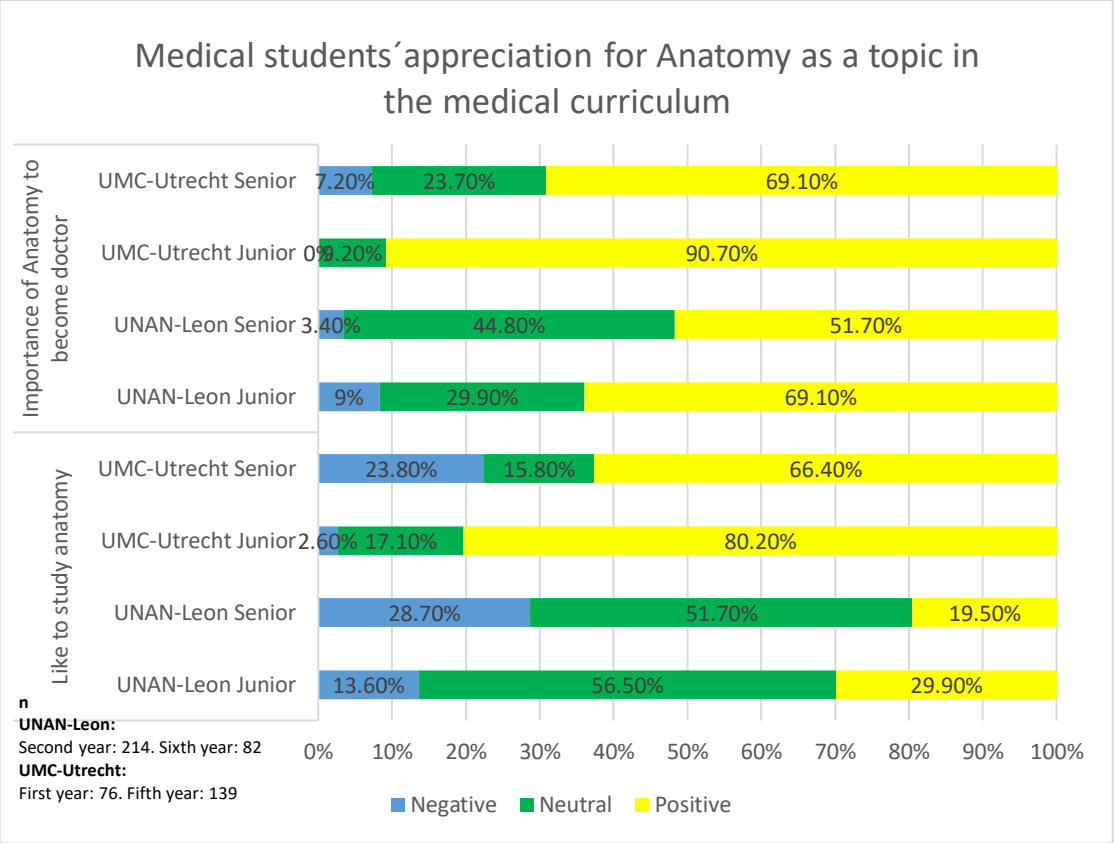

Figure 1. Frequency of Medical Students´ Appreciation for Anatomy as A Topic in the Medical Curriculum

Overall, most respondents in all four groups (in UNAN-Leon, 81.8% for juniors and 54% for seniors; in UMC-Utrecht, 59.2% for juniors and 55.7% for senior students) agreed that their medical curriculum provides an adequate amount of anatomy teaching (p = 0.000). However, a substantial percentage of senior students in both universities still qualified for the amount of anatomy teaching as being too little, 40.2% in UNAN-Leon and 43.2% in UMC-Utrecht. In UMC-Utrecht, while most junior and senior students considered the educational quality satisfactory (68.4% for junior students and 56.1% for senior students), there is still space for improvement. In UNAN-Leon, however, less than 8% (junior students) and 5% (senior students) considered the quality satisfactory (Figure 2).

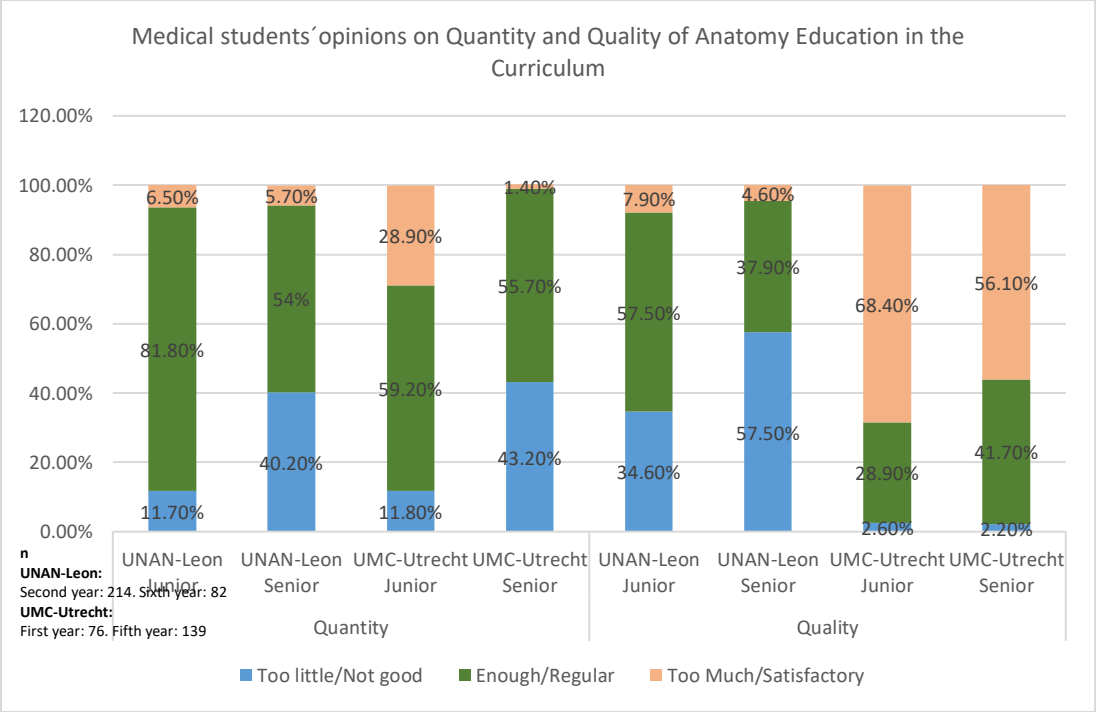

Figure 2. Frequency of Medical Students´ Opinions On Quantity and Quality of Anatomy Education In the Curriculum

When we asked if they had ever considered becoming an anatomy teaching assistant student, the answers were similar in both universities. Senior students had not considered becoming an anatomy teaching assistant (67.8% for UNAN-Leon and 54.6% for UMC-Utrecht). In comparison, junior students considered becoming one (59.4% for UNAN-Leon and 63.1% for UMC-Utrecht) (p = 0.000 for both universities). The universities showed differences in students' interest in becoming teaching assistants versus opting for an entire career in anatomy. While in UNAN-Leon, a minority did consider anatomy as a career (32.3% for junior and 16% for senior students), in UMC Utrecht, very few students ever considered anatomy as a career (15% for junior and 4% for senior students) (p = 0.000 for both universities) (Figure 3).

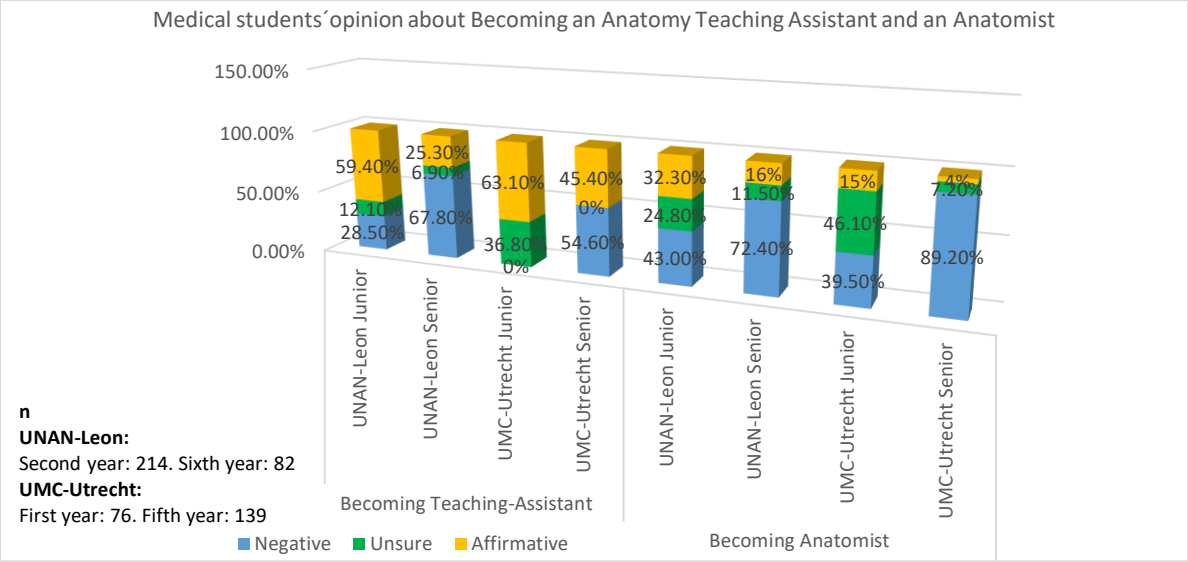

Figure 3 Frequency of Medical Students´ Opinions about Becoming an Anatomy Teaching Assistant and an Anatomist

Most students in both universities acknowledge that anatomy is more of interest for educational purposes than as a scientific domain of research: 61.7% for juniors and 58.6% for seniors in UNAN-Leon and 61.8% for juniors and 71.2% for seniors in UMC-Utrecht (p= 0.046 and p= 0.001, respectively) (Table 1).

Table 1. Frequency of med students' opinions about the most exciting aspect of anatomy education

University	Academic year	N	Education	Research	Other aspect
UNAN-Leon	Second	214	61.7%	31.3%	7%
	Sixth	87	58.6%	25.3%	16.1%
UMC-Utrecht	First	76	61.8%	22.4%	15.8%
	Fifth	139	71.2%	23%	5.8%

We explored student opinions about the effectiveness of 13 distinct educational methods for anatomy. Junior students´ views were similar in both universities, and they rated the surgery teaching method as the most effective (in UNAN-Leon, 80.4%; in UMC-Utrecht,89.5%). While senior students´ opinions differed, UMC-Utrecht dissection received the highest appreciation for its effectiveness (91.4%), while UNAN-Leon prosection was rated highest (72.4%). The method with the lowest rating for effectiveness in the four groups of students was "active clay or plasticine modeling" in UNAN-Leon, with 19.5% for seniors and 8.4% for juniors; in UMC-Utrecht, 36.7% for

senior students. In general, all methods obtained higher appreciation from UMC-Utrecht students. In UMC Utrecht, we noticed a shift in preference between the first and fifth years from lecture to self-directed learning (Figure 4).

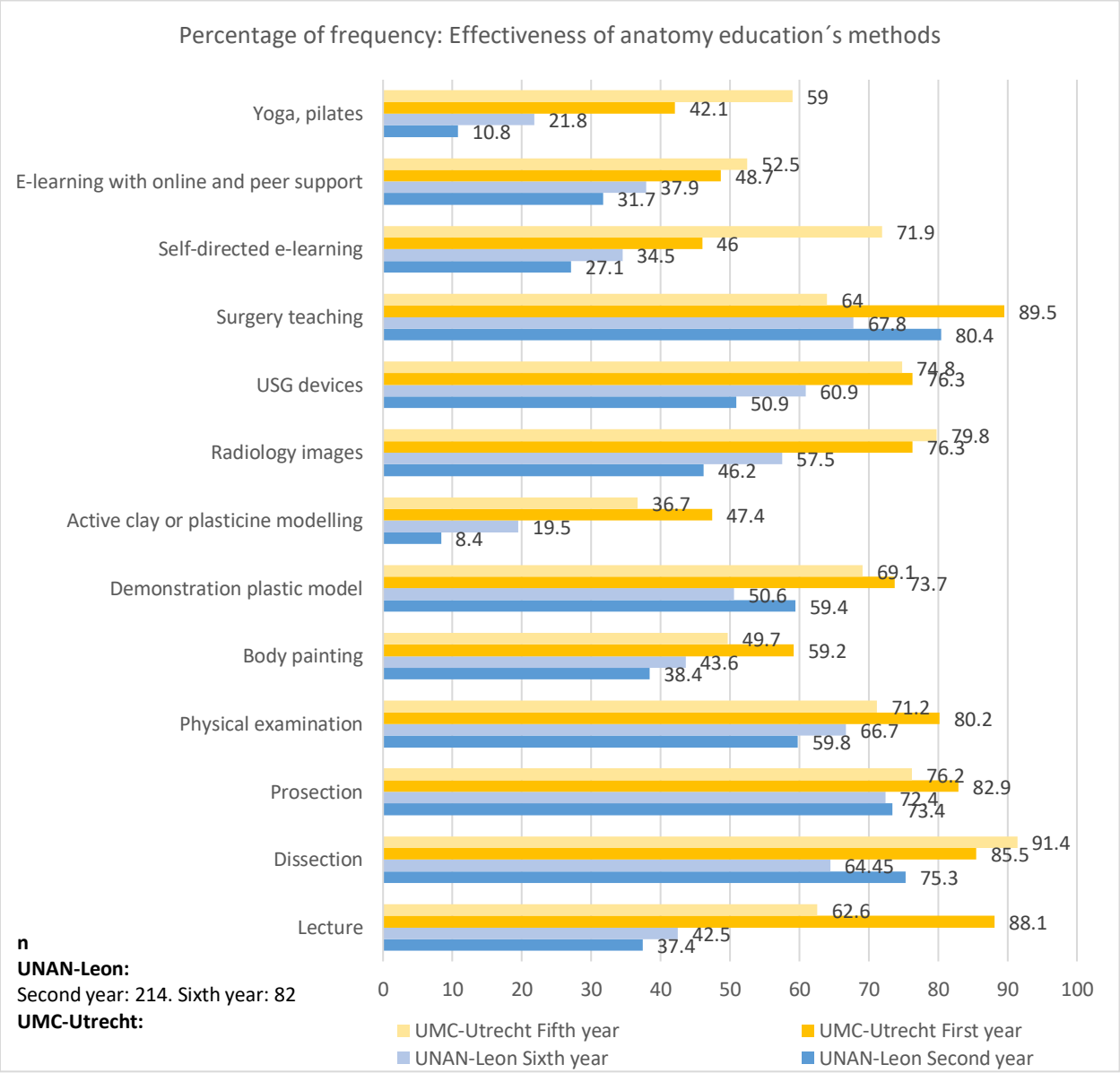

Figure 4. Effectiveness of anatomy education´s methods according to junior and senior medical students of UNAN-Leon and UMC-Utrecht

5.5 Discussion

We compared the perceptions and preferences of medical students from a Nicaraguan university (UNAN-Leon) and a Dutch university (UMC-Utrecht) regarding anatomy. Most students agreed about the importance of anatomy for becoming a doctor. Students considered the quantity of anatomy in their curriculum to be enough. However, most Nicaraguan medical students were neutral about their preferences for studying anatomy, while Dutch students appreciated the subject well. The Dutch students considered its quality satisfactory, while most Nicaraguan students thought that anatomy education could (2nd year) or must be (6th year) improved. Many considered serving as an anatomy teaching assistant, but few considered becoming an anatomist. Among the preferred educational methods in anatomy, dissection, prosection, and surgery teaching were considered the most effective.

Based on our findings, we can speculate why Dutch students like anatomy better than Nicaraguan medical students and have a more positive perception of the quality of anatomy teaching. One explanation may be that Dutch students spend more hours on anatomy, enabling them to understand better or experience more diverse teaching forms, making the subject more attractive. More exposure could generate more interest.

Nicaraguan medical students only encounter anatomy through lectures and practical classes. Teacher-oriented methods and the lack of diversity in teaching approaches could be boring. Moreover, the limited possibilities in a low-resourced country to maintain the quality of the teaching materials may influence this perception. More variation in teaching methods could generate more interest because course planning and curriculum structure are significantly associated with students´ satisfaction more than the time of teaching (22).

In all groups, most students regard the quantity of anatomy in their curriculum as sufficient. Still, the significance of anatomical education for one´s medical career increases over time, at least among Dutch students. UMC-Utrecht´s students appear to acknowledge the importance of teaching enough anatomy only by the end of their studies rather than in the beginning, as the percentage of considering anatomy to be too many drops from 29% to 1.4%.

Overall satisfaction varies across the continuum of medical education (23). Stressing the relevance of one´s career could generate interest. Interestingly, while the appreciation of anatomy education is higher in Utrecht, and many students have considered becoming an anatomy assistant during their medical studies, very few consider anatomy a career.

This contrasts with the UNAN-Leon students, as one in every five (for junior) or six (for senior) students indicate that they should seriously consider a career in anatomy. Possibly, in a country with an unemployment rate of 6.2% (24) and a drop in GDP to 4.8% (25) in the third quarter of 2018, and where private medical practice is not

much in demand, working in a university as a professor in anatomy or any other discipline becomes an essential option for professional life. Despite a lower appreciation of anatomy, the interest in becoming an anatomist can be higher, likely explained by the economic context.

Our findings about the perceived importance of and interest in anatomy concord with the literature (1,3–7,26–29). When considering how interesting anatomy is, it is essential to differentiate between anatomy as a topic of study and anatomy as a career option. Concerning anatomy as a topic of study, UMC-Utrecht´s students' opinions were positive, while UNAN-Leon´s students´ views were neutral. This difference could be due to the different implementation of the subject.

Anatomy as a career option means working in an academic or research field without patient contact. As contact with patients is highly motivating for medical students, anatomy may be interesting primarily if it supports that purpose, not as a topic of research or education per se. Most students did not consider anatomy a career, probably because their first motivation and purpose is to be in contact with patients.

Becoming an anatomy teaching assistant was an option senior students considered, although most decided not to pursue. This may be because they had explored all medical disciplines and experienced the clinical phase of medical training, which strongly emphasizes disease processes, treatment, and management.

In addition, some students perceive anatomy as most important in emergency rooms and surgical and radiological specialties but not in fields like internal medicine and pediatrics, where physiology and pharmacology are considered most important (30). Another factor could be the lack of job opportunities and adequate research facilities, which limits the uptake of anatomy as a career option (2), especially in a country with more than 80 percent of informal employment and a lack of decent jobs and economic opportunities for young people (31).

As for the effectiveness of methods of anatomy education, the fact that junior students preferred watching surgery may be explained by its novel and exciting aspects for someone who has never seen an operation. It may come close to the prospect of a future professional perspective. One might question who is better equipped for anatomy teaching, an anatomist or a surgeon. A surgeon may benefit from extensive clinical experience while teaching applied anatomy and may focus more on the thorax and abdomen. An anatomist teaches with a more integral focus: the body as a complete entity, including all anatomical regions, namely the head and neck, the back, and the limbs. Moreover, as teachers, anatomists may pay attention to generalizable concepts of body construction, which enhances understanding of anatomy.

We believe that complementary morphological teaching by anatomists and clinicians is beneficial as it combines teaching the fundamentals of the human body morphology by all-around anatomists with teaching applied anatomy as needed in surgery and other clinical disciplines. The finding of senior students' preference for

anatomy methods, such as prosection and dissection, may be attributed to the fact that they have practiced those methods quite enough in medical school and acknowledge the benefits of it. Conversely, junior students of both universities had not had contact or/or experience in dissection courses at the time of the survey.

The outcomes in the preferences and opinions of the study population on anatomy education may be valued against the cultural and resource differences described in the introduction section. The Dutch´s economic and cultural characteristic might explain their opinion about the effectiveness of different anatomy education methods and the quality of anatomy education, simply because all are realistically feasible if schools would find them compelling. Also, they have more experience with a variety of methods. Nicaraguan people (as Hispanic culture) are more traditional people (32), preferring to retain aspects that they already know or do; for example, the classic anatomy education methods such as dissection, prosection, surgery teaching, and lectures are considered most effective while novel but unknown methods such as yoga, pilates, and body painting, are considered least effective; but this cannot be disentangled from differences in economic circumstances Hofstede´s dimensions may all be relevant (13).

While both medical schools have a similar integrated curriculum, we found differences in students´ perceptions, especially about the effectiveness of non-conventional teaching methods. This probably reflects a resistance to change among Nicaraguan medical students. That could indicate that the main constraints are not economic but psychological, making it more likely that differences in teaching and curriculum are more influential than educational resources.

Limitations of the study

The low response rate in one of the participating universities (UMC-Utrecht) does not allow us to generalize our outcomes by stating that medical students have the same perceptions about anatomy education. Therefore, further investigations are needed to confirm the study's conclusions, possibly enriched with qualitative explanations to support some of the more speculative inferences we made.

This preliminary study only addresses the perceptions of a group of university students; our findings would be supported if our study were replicated with students from other faculties from both universities, even from both countries.

Conclusion and Recommendation

Our study supports the impression that students in countries with more resources have a more favorable attitude toward anatomy education than students in less affluent countries, independent of the adequacy or amount of anatomy education and their interest in becoming anatomists. This conclusion deserves support from additional studies in different countries and further research approaches.

5.6 Acknowledgments

The authors wish to thank Lilliam Mejía, Diego Robles, and Norvin Sotelo, who were UNAN-Leon´s medical students and collaborated on collecting data.

5.7 Compliance with Ethical Standards

Ethical approval: Participation in the study was voluntary. Students have explained the purpose of anonymity and survey data handling. In UNAN-Leon, approval was obtained from the Faculty of Medical Sciences authorities. In UMC Utrecht, approval was obtained from the Netherlands Association for Medical Education Ethical Review Board.

Informed consent: Oral informed consent was obtained from all participants included in the study.

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5.9 Annexes

Appendix 1

Questionnaire

Dear student,

This survey inquires about your views on anatomy education. How important do you think anatomy education is for the training of doctors? How much do you like it? Have you ever thought about teaching it yourself? And what do you think of different approaches to anatomy education?
These questions are being asked in a short survey for junior and senior medical students at the University of Léon in Nicaragua and the University of Utrecht in the Netherlands. The answers will help to develop anatomy education in well-resourced and less well-resourced medical schools.

The answers to this questionnaire will be processed anonymously. For reasons of ethical approval, we would like to ask your permission to use your answers in research reported and intended for publication in a scientific journal. We will retain the data for five years, as prescribed by ethical rules for scientific research.

1. I permit the use of my answers anonymously in a research report
   a. Yes
   b. No

2. If you want to receive a preliminary outcomes report, please enter your email address. If you wish to remain completely anonymous, please create a new email address, e.g., using Google's Gmail or other service. We hope to send you the outcomes before the end of 2016

Email address:	

3. What is your age?
   a. < 20
   b. 20-24
   c. >24

4. What is your gender?
   a. Female
   b. Male

5. Please state your appreciation for anatomy as a topic in the medical curriculum, like studying anatomy, most minor of all issues in the curriculum
   a. I like studying anatomy less than most other topics
   b. I like studying anatomy just as much as most other topics
   c. I like studying anatomy more than most other topics
   d. I like studying anatomy most of all topics in the curriculum

6. Please state your view on the importance of extensive anatomy study to become a doctor not important at all
   a. Not very important
   b. Just as important as most other topics
   c. Rather important
   d. Of utmost importance

7. Please state your opinion about the ***quantity*** of anatomy education in your curriculum: Our curriculum provides too little education in anatomy
   a. Our curriculum provides enough but not too much anatomy education. Our curriculum offers too much anatomy education

8. Please state your opinion about the ***quality*** of anatomy education in your curriculum
    a. The quality of anatomy education in our curriculum must be improved
    b. The quality of anatomy education in our curriculum can be improved
    c. The quality of anatomy education in our curriculum is satisfactory

9. How do you think about becoming an anatomy teaching assistant?
    a. I would never consider this / I have never considered this
    b. I have considered it but decided not to choose it / I have considered this but chose not to
    c. I am entirely unsure about this / I have been or still am an anatomy teaching assistant
    d. I am seriously considering it but have not made up my mind [n/a]
    e. I would like to become an anatomy teaching assistant [n/a]

10. How would you think about becoming an anatomist for a career?
    a. I would never consider this
    b. I have considered it but decided not to choose it
    c. I am entirely unsure about this
    d. I am seriously considering it but have not made up my mind
    e. I would like to become an anatomist

11. If you find anatomy interesting, what aspect would be most interesting? (check one, more than one, or none)
    a. Education in anatomy
    b. Research in anatomy
    c. Other aspects

12. Please indicate which methods of anatomy education you find most effective

	Among least effective methods	Not very effective	Not more or less effective than other methods	Pretty effective	Among most effective methods
a. Lectures in anatomy	1	2	3	4	5
b. Dissection of corpses by students	1	2	3	4	5
c. Prosection of corpses by teachers	1	2	3	4	5
d. Anatomy by physical examination	1	2	3	4	5
e. Live body painting	1	2	3	4	5
f. Demonstration through plastic models	1	2	3	4	5
g. Active clay or plasticine modelling	1	2	3	4	5
h. Anatomy through radiology images	1	2	3	4	5
i. Anatomy with bedside ultrasound devices	1	2	3	4	5
j. Anatomy through surgery teaching	1	2	3	4	5
k. Self-directed e-learning	1	2	3	4	5
l. E-learning with online and peer support	1	2	3	4	5
m. Anatomy by yoga, pilates, or similar	1	2	3	4	5

There is space for additional remarks or clarification about your views on anatomy and its methods. You may write in English or another language.

Thanks for your collaboration

CHAPTER 6

APPROACHES OF ANATOMY TEACHING FOR SERIOUSLY RESOURCE-DEPRIVED COUNTRIES

This chapter has appeared as follows:

Chang Chan AY, ten Cate O, Custers EJFM, van Leeuwen MS, Bleys RLAW. Approaches of anatomy teaching for seriously resource-deprived countries: a literature review. Education for Health 2019;32(2):62-74

Author contributions:

Conception of the study:	AYCC, EHFMC and OtC
Data collection:	AYCC
Data analysis:	AYCC, RLAWB, EHFMC, MSvL, OtC
Writing the first version of the manuscript:	AYCC
Critical review and adding import intellectual content:	RLAWB, EHFMC, MSvL, OtC

All authors consented to the final version before submission to the journal.

6.1 Abstract

Background and aim. Teaching anatomy is an essential but expensive part of the medical curriculum, potentially more than many countries can afford. Cost-effectiveness is of utmost importance in the search for efficient methods in such countries. This contribution aims to review the literature on anatomy teaching methods and evaluate these for feasibility in resource-deprived countries.

Method. A literature review was carried out to identify distinct approaches to anatomy teaching published between 2000 and 2014, using the databases of PubMed, Wiley Online Library, Elsevier, HINARI, Springer, and ERIC. The approaches found were compared against their conceptual, operational, technical, and economic feasibility and Mayer´s principles of effective instruction.

Results. Our search yielded 432 papers that met the inclusion criteria. We identified 14 methods of teaching anatomy. According to their conceptual feasibility, dissection and technology-enhance learning approaches appeared to have more benefits than others. Dissection has, besides benefits, many specific drawbacks. Lectures and peer teaching showed better technical and economic feasibility. Educational platforms, radiological imaging, and lectures showed the highest operational feasibility. Dissection and surgery were found to be less feasible because of operational, technical, and economic characteristics.

Discussion. Based on our findings, the most important recommendations for anatomy teaching in seriously resource-deprived countries include a combination of complementary strategies in 3 different moments: lecturing at the beginning, using a virtual learning environment (for self-study), and at the end, using demonstration through prosected specimens and radiological imaging. This provides reasonable anatomy insights through dead and living human bodies and their virtual representations.

6.2 Acknowledgments

The authors thank Dr. Ligia Cruz, MD, PhD, and Dr. Sonia Acevedo, MD, Family doctor specialist, for their collaboration in reviewing and editing the paper.

6.3 Introduction

Anatomical science has long been regarded as a cornerstone in medical education (1–4). Knowledge of the structure of the human body is essential to understand how both structure and function are modified by disease (3,5), but also to perform a good physical exam (4). For ages, the teaching of anatomy has dominated the medical curriculum (2,5–12). In the second half of the 20th century, the curricula changed, and more time became devoted to other disciplines, often at the cost of anatomy (13,14). To maintain the required anatomy knowledge of medical students, many schools have explored and developed new and more efficient teaching approaches. However, a factor considered less frequently is the cost-effectiveness and feasibility under challenging circumstances. Teaching anatomy in a dissecting room is one of the most expensive components of the undergraduate medical curriculum (4). Many countries worldwide are seriously deprived of financial means but are at the same time in high need of a well-trained medical workforce.

The medical education literature has abundant examples of new methods of teaching anatomy. Most publications claim the new strategy has succeeded (15–25). Failing education is rarely reported. Most reports do not compare approaches to anatomy teaching but describe a stand-alone educational method. We aimed to identify educational strategies that fit the student's learning needs, specifically in low—and middle-income countries (LMIC), and to classify methods according to educational approach, resources, and feasibility.

This paper aims to review the state-of-the-art anatomy teaching available in the scientific literature over the last 15 years. It provides an overview of the taxonomy of methods, their benefits and limitations, and a focus on cost-effectiveness.

6.4 Methods

We performed a scoping review with a realistic purpose: to answer the question: What different approaches are used to teach gross anatomy? Which of them is feasible in LMIC?

A review of original articles searched manually in scientific journals on medical education likely to cover anatomy education was performed covering 14 years (2000-2014) using the following electronic databases and virtual journal libraries: Pubmed, ERIC, Wiley Online Library, HINARI, SPRINGER, Elsevier sciences direct, LWW, Taylor & Francis. The starting year of 2000 was chosen as an estimated time when electronic media would be substantially introduced in anatomy teaching. All titles and abstracts were reviewed by the first author and were excluded if they did not meet the inclusion criteria.

The inclusion criteria were original articles that addressed one or more approaches, strategies, and methodologies in undergraduate anatomy teaching in health professional careers and the English language.

The articles were categorized as *Traditional* (methods that commonly have been used in medical schools; these methods are mainly teacher-centered and non-integrative) and *Innovative* (strategies that emphasize active, self-directed learning and integrative courses; those strategies have been implemented in medical schools for 50 years or less, due to anatomy teaching being very traditional) (26,27). Next, the approaches found were rated on conceptual feasibility (to supplement academic learning.), organizational feasibility (organizational infrastructure and time needed), technical feasibility (managerial knowledge and skills, human resources, and technological capacity needed), and economic feasibility (cost of the didactic materials and resources required for both students and teachers) and instructional effectiveness. (Figure 1)

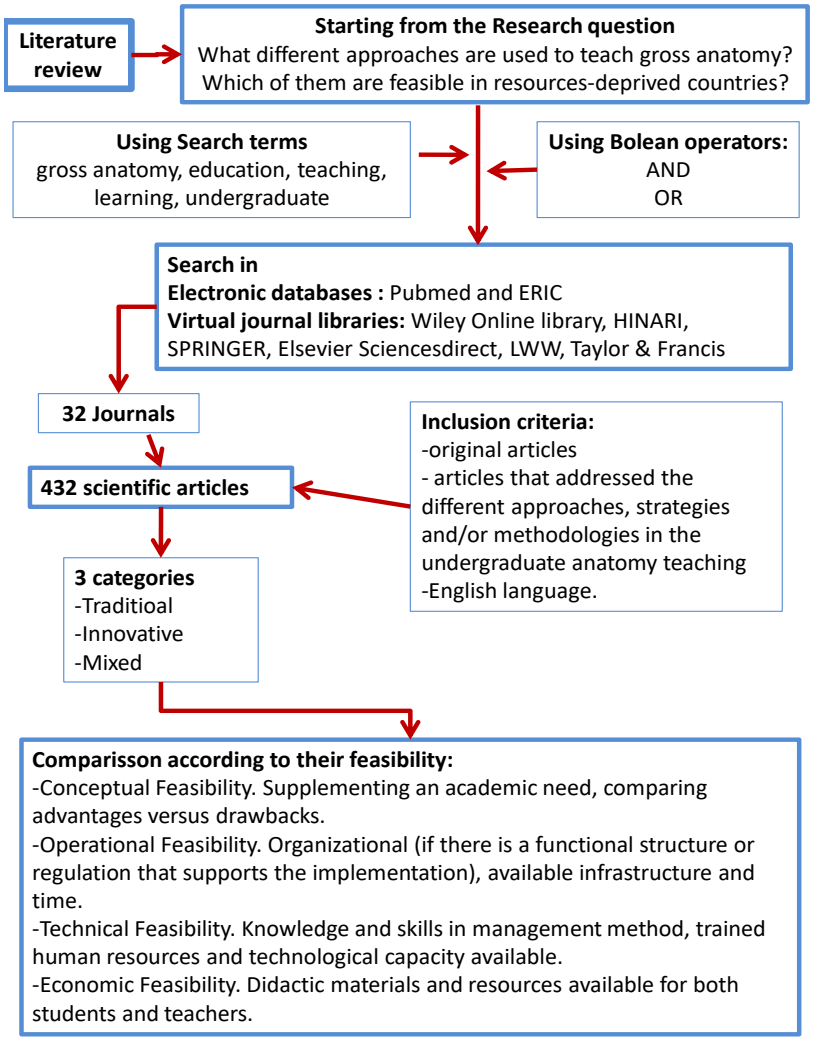

Figure 1. Literature Search Strategy

Instructional effectiveness was operationalized by analyzing the teaching strategies and relating them to the nine principles that Mayer proposed (28):

1. Coherence principle: eliminate extraneous material.
2. Signaling principle: highlight essential material.
3. Contiguity principle: Place printed words near corresponding graphics.
4. Pre-training principle: provide pre-training in names and characteristics of critical concepts.
5. Segmenting principle: break lessons into learner-controlled segments.
6. Modality principle: present words in spoken form.
7. Multimedia principle: present words and pictures rather than words alone.
8. Personalization principle: present words in a conversational or polite style.
9. Voice principle: use a human voice rather than a machine voice.

All methods found in the literature were viewed from the perspective of instructional theory using Mayer's instructional design principles.

6.5 Results

From an initial yield of 607 anatomy education articles, 432 original articles met the inclusion criteria. We identified 14 methods of teaching anatomy that can be further categorized. Next, we compared the methods with conceptual, operational, technical, and economic feasibility (see Table 1). All teaching methods are described with their benefits and limitations in Table 2.

1. *Lectures*

Didactic lecturing in anatomy education is as traditional as dissection and follows the learning objectives for students (12). It is characterized as a teacher presenting theoretical content to a group. The event requires the participants' presence at a specific time and location (29).

2. *Dissection*

Dissection, one of the main anatomical learning tools in medical schools, has been used worldwide in teaching anatomy for more than 400 years (30). Dissection of human cadavers is the physical exploration of a dead human body through cutting and is essentially a regional-based approach to learning topographical anatomy (31).

3. *Demonstration*

Three anatomical demonstration modes can be distinguished: prosection of corpses, using plastic models, and plastination.

Table 1 Anatomy Teaching Approaches

<table>
<tr><th>Approach</th><th colspan="3">Strategies</th><th>Resources</th></tr>
<tr><td rowspan="3">Traditional (26)</td><td colspan="3">Lectures/tutorials</td><td>Books, atlas</td></tr>
<tr><td colspan="3">Dissection</td><td>Cadavers</td></tr>
<tr><td colspan="3">Demonstration</td><td>Prossected cadavers
Plastinated cadavers
Plastic Models</td></tr>
<tr><td rowspan="11">Innovative</td><td>Small group</td><td colspan="2">PBL</td><td></td></tr>
<tr><td rowspan="3">Living body</td><td colspan="2">Radiological Imaging</td><td>X-Ray, CT, USG, MRI</td></tr>
<tr><td colspan="2">Surgery observation</td><td>Operating room</td></tr>
<tr><td colspan="2">Physical examination</td><td>Peer examination. Simulated patients</td></tr>
<tr><td colspan="2">Body painting/ Drawing</td><td>Paint, paintbrush</td></tr>
<tr><td rowspan="3">Technology-enhanced learning</td><td>4th generation of e-learning</td><td>Computer-assisted learning</td><td>Informatic resources: software, CD ROM, Apps</td></tr>
<tr><td rowspan="2">Telematics: 5th generation of e-learning: web-based learning</td><td>Educational platforms</td><td rowspan="2">Learning Management System (LMS)
Tools of Web 2.0</td></tr>
<tr><td>Social platforms</td></tr>
<tr><td rowspan="3">Miscellaneous</td><td rowspan="3">Unconventional</td><td>Comics trips/ Limerick</td><td rowspan="3">Diverse</td></tr>
<tr><td>Yoga & Pilates</td></tr>
<tr><td>Plasticine /clay modeling</td></tr>
</table>

Prosected cadavers provide learners with pre-dissected material. Some universities have chosen to teach anatomy through prosected cadavers and specimens and have abolished dissection courses (26). Leung et al. (2006) found course hours in the prosection class to be 74% shorter than the dissection class. One study found knowledge retention of anatomy five years after training to be similar in the prosection group and dissection groups (32). Plastination is a relatively new advancement in cadaveric science; an effective technique of tissue preservation of entire organs or cross-sectional body slices was introduced in 1987. Using polymers such as resin, silicone, and polyester gives differing mechanical properties that ultimately result in robust, dry, odorless, and life-like specimens, which can be used well in an educational capacity in gross anatomy and radiology (12).

4. *PBL (Problem-Based Learning)*

A PBL curriculum enables students to integrate basic and clinical science, evidence-based decision-making, clinical reasoning, and psychomotor skills (33,34). PBL´s application to anatomy teaching requires a close follow-up of each student with

regular feedback on their work. Students create and share learning objectives related to anatomy and obtain the necessary information through textbooks, the internet, assigned disciplinary resource staff, skill laboratories, anatomy museums, and audio-visual aids. Anatomy is incorporated into most problems and their accompanying learning activities; the proportions vary according to the problem or system unit (24,33).

5. ***Anatomy in the living body: physical examination.***

Anatomy can be studied in the living body through physical examination (through simulated patients and peer examination), where the surface anatomy is vital. This method can be beneficial in studying some systems and organs such as muscles, bones, joints, the peripheral nervous system (through the study of tendon reflexes), abdominal organs, and cardio-respiratory organs (35,36).

Table 2. Benefits and limitations of anatomy teaching methods.

Anatomy teaching methods	Benefits	Limitations
Lectures	- Guide the student on the objectives and learning goals to be achieved. Lectures force students to focus on facts and can improve short-term knowledge retention (82). - Can efficiently reach large numbers of students (unlimited audience size) (29). - Can be easily supported by expert-driven visual aids (clinical photos and computer animation) (29). - It´s considered efficient for presenting information, providing explanations, and fostering enthusiasm for learning (It can motivate new learners if the lecturer can highlight exciting aspects and the importance of the subject in their professional training) (83). - By adjusting existing resources, lectures can be combined reasonably efficiently and cost-effectively with other activities like e-learning (83). - Classic frontal teaching setups can put students into personal contact with teachers (29).	- Lectures require the participants' presence at a specific time and location. The audience size is only limited by the capacity of the lecture hall or seminar room (29). - The traditional lecture format assumes that all students are auditory learners and acquire the same information presented orally at the same pace without dialogue with the presenter (84). - It´s ineffective when the instruction goals do not provide enough contact time for more profound learning activities. (83) - Students listen passively to lectures and read their text but seldom participate in activities (83,85). - Lectures often fail to excite students by allowing them to discover the internal features and functions of the human body for themselves (85). - Communication is predominantly one-way and based on the auditory channel, supported by visual aids (29).
Dissection	- Dissection is the first exposure of students to the human body, leading to a better	- There is an emotional impact of dissection: anxiety and emotional

Anatomy teaching methods	Benefits	Limitations
	understanding and learning of anatomy (6,86). -The practice of dissection in the early stages of medical training has proven beneficial in the development of the three types of skills to be competent: cognitive (understanding the three-dimensionality of the structures and their anatomical relationships, recognition of anatomical variants through observation), psychomotor (developing fine motor control and touch-mediated perception of the cadaver/patient, distinguish the texture of the different tissues of the body, haptic perception of 3 D, learn to handle instruments minor surgery) and affective (professionalism, teamwork, respect for the human body) and is an attractive procedure for medical students (2,4,25,30,47,63,87,89). - Students are engaged in self-directed learning to self-improve their anatomical skills (4,88). - Developing competence in diagnostic imaging (spatial reasoning skills to understand and interpret imaging data) (87). - Developing competence in training for medical specialties (semiotic, surgical, and therapeutic approach) (89,90). - Dissection is an opportunity to reinforce familiarization and respect for the body and integration of theory into clinical practice (12). - Dissection helps students recall what they learned (30). - Dissection helps to enhance students' respect towards the human body (30). - The opportunity for a student to touch the materials and talk to a teacher seems a friendlier way to teach and to further contribute to the hidden curriculum (37).	disturbance have been described (52,91, 92). - Dissection can be expensive; there are high economic costs of transporting, maintaining, and disposing of cadavers (4,25,36,59,63–65). - There are fewer qualified gross anatomy faculty and fewer anatomy graduate students to teach anatomy through dissection (25,52,59,60). - Dissection and self-instruction time are inadequate (usually lengthy) (30,52). Students spend long hours at the dissecting table (67). - As dissection uses formalin solution has associated hazards following exposure to formaldehyde, including allergic dermatitis, ocular and airway disorders, and carcinogenesis (36,38,59,66). - Some areas, such as the perineum, are inherently difficult for novice dissectors to display clearly (89). - Some studies report that dissection classes can be associated with physical and emotional stress (30). - Some students are concerned about the dissection smell (30,36,52). - Studying anatomy through the dissection of a cadaver can cause a loss of the richness of color and texture found in organs in fresh tissue dissection (autopsy) (62). - The number of available cadavers may depend on the local culture and habits of donation in the population. Some countries have cultural and social barriers to dissection (52,64,67,86,93). - For some institutions, cadavers may not be available (59).
Demonstration	- Prosection makes more time for teaching, learning, and review (6,46,89).	- Plastic models fail to maintain the natural variance or pathology of the human body (12,65).

Anatomy teaching methods	Benefits	Limitations
	- Prosected cadavers maximize the increasingly scarce resource of cadavers and teachers (46). - Prosection maintains some of the advantages of dissection in relation to the skills acquired (94). Plastic Models enable learners to explore, visualize, and understand the interrelations of anatomical structures, including what lies beneath their examining fingers or stethoscope, with minimal wear and tear (65,94). - Plastic models have a longer shelf life, making them an inexpensive supplement (65). Plastic specimens can be modeled to perfection and possess a much longer shelf-life than cadavers. However, plastic models do not account for biological variation and lack pathological authenticity, which can lead to errors in physical examinations in clinical settings (12). - Plastination gives differing mechanical properties, resulting in robust, dry, odorless, and life-like specimens (realistic) (12,66). - Plastinated material allows students to repeatedly study the specimens with minimal wear and tear (12,66). - Plastinated material is more robust and can be handled safely and stored at room temperature (46). -Teaching sectional anatomy using plastinated anatomical sections improved student interpretations of CT sections (95). Plastinated specimens can be handled without gloves and do not require any special storage conditions or care. They also prevent exposure to toxic substances (e.g., formaldehyde) (66).	- Plastic models are associated with a low fidelity and show only a small number of structures, which often lack of accurate representation of shape and surface details (65). - Commercial models of human organs are usually prohibitively expensive and too large for students to purchase and handle (39). -The rigidity of the tissues limits the use of the plastinated model (46). - Prosection is a passive learning experience (96). - Learning with plastinated prosection was perceived to be compromised because of limitations regarding tactile and emotional experience (97). -During plastination, there are several stages at which the process can be brought to a long-term halt (98). A realistic estimate of the cost of equipment for a plastination laboratory is approximately U$50000 (98), which is expensive and, therefore, unavailable to some universities in developing countries.
PBL	-PBL stimulates retention and acquisition of basic science knowledge (continued learning) (27). - PBL may be used to support the introduction of the anatomical basis of a region (24,33).	- The learning of detailed anatomy is left to the students themselves, resulting in a risk of missing important points; therefore, sometimes students often feel that there might be gaps in their knowledge (24,34).

Anatomy teaching methods	Benefits	Limitations
	- Present a more integrated approach, in that the normal structure and function of the human body are studied concurrently with the pathologies and clinical applications (12,65,99). - PBL aims to achieve horizontal and vertical integration, where the main feature is the integration of different basic science disciplines in one course (12,27,104). - Students become more independent, developing autonomy in their own learning process (self-directed learning) (12,26,27,90). - In the PBL sessions, students prepare group presentations to classmates, adding a dimension to using the knowledge that prepares them to present information to patients (100). - PBL produces more self-assured and practically-minded doctors (3). - It promotes cooperative learning as students work together to solve problems and discuss ideas (65).	- Students may become more interested in the clinical aspects of a problem and neglect the underlying basic science knowledge (27). - There is growing evidence that PBL curricula for anatomy may result in insufficient knowledge (65).
Physical (Peer) examination	- To provide a method of gaining insight into spatial relations of the internal organs (35). - To assist the students in overcoming their natural reticence to professional physical contact in an early phase of their medical training (35). - Students can develop an understanding of the anatomy in context and their sensitivity towards patients' needs (12,36,101). - It´s a method of studying living anatomy, it means studying the structure and function of organs (25).	- Difficulties may arise with students from particular religious backgrounds or who have issues relating to body image (36). - There are sensitive areas, such as the female breast and the groin, in both sexes that are not part of the peer examination process (36,101). - Internal examination is taught in clinical skills, not as part of the anatomy program (36,101).
Radiological imaging	- The use of radiologic images in a dissection course was found to increase students´ interest in gross anatomy, and the integration of radiologic imaging into anatomy courses improved students´ ability to identify anatomic structures and long-term knowledge retention (37,39,71,98). - An early introduction and correlation between cross-sectional images and sectional/ topographical anatomy greatly	- To obtain body-specific images, the cost of scanning bodies each year for students dissection is prohibitive (104). - Requires more intensive supervision in a limit group size and also more prepared teaching staff (72). - For anatomy and radiology courses the specimens and images must be prepared carefully and utilized in the most efficient way (37).

Anatomy teaching methods	Benefits	Limitations
	facilitate reading/interpretation of radiological images for students which it´s essential to understand the consultation reports from radiologists in clinical practice, reducing the gaps between the learning environment and the practice environment (17,37,66,71,99,108). - It promotes the integration of clinically relevant content, facilitates understanding anatomy, and improves clinical thinking (72). -It´s a method of studying living anatomy, it means, study the structure in 3D and function of organs (25,46). -Students see the direct relevance and applications for their future clinical work, which improves their motivation to learn (72,102). - Studying living anatomy using ultrasound adds a dynamic element to the study of anatomy that the cadaver cannot (25). - Enhance the recall of anatomical information on radiological images (95). -Radiological images (CT, MRI, PET, SPECT) can provide much information about the morphology, function, and metabolism of the human body (103). - The images can be manipulated to remove irrelevant tissues, allowing detailed study of particular organs (46).	- It needs extra time invested in collecting clinical cases appropriate (40). - X-ray films, CT and MRI scans, can be considered static, and it is difficult to impress on students the dynamic nature of living anatomy (71). - The Budget of many anatomy departments may not be large enough to support purchase of the USG, CT or MRI machine (71).
Observation of surgeries	- Surgery allows students to apply what they have learned from books, videos and models to real-life patients (44). - The mix of anatomy and surgery in interdisciplinary courses could improve deep medical comprehension and clinical thinking (72). - Students with access to surgical skills have more profound insights into topographical anatomy (72). - The fact that students see the direct relevance and applications for their future clinical work improved their motivation (72).	- Limited access to theatres (particularly for pre-clinical students), variability in teaching quality, and limited opportunity to explore beyond the scope of the operated area are drawbacks (44). - Integrating anatomy and surgery teaching requires more intensive supervision in limited group size and more teaching staff (72).
Body painting or drawing	- It helps the learner gain insight into the dimensions and positions of organs and	- Passivity of the model person and his/her loss of interaction with the

Anatomy teaching methods	Benefits	Limitations
	surface projections of internal viscera (31,35). - It helps to become familiar with essential surface landmark anatomy, easy palpation, and peer examination (22,31,35). - Teaching clinical topics in topographical or regional anatomy will resemble anatomical impressions that must be made during physical examination in patient care (23,31). - To develop students' understanding of the living body in context, and to develop sensitivity toward patients´ needs (23). - In body painting, structures such as the heart, pericardial cavity, lungs, and pleural cavities can be painted with realistic colors (36). - Body painting can be effectively used in conjunction with palpation and auscultation (31,36). - Body painting promotes self-active and tactile learning, aiding students´ retention of anatomical knowledge (22,23,31). -Body painting facilitates learning spatial relations of underlying anatomy and develop confidence in eliciting clinical signs (23). -Body painting is a feasible and motivating tool in large class settings (23,35). - Body painting is universal across learning styles, especially visual and kinesthetic (22,23,31). - Students report with body painting they have fun (22,23,35).	teaching of gross anatomy and/or physical examination (31,35). - Natural sense of embarrassment at nudity (35). - The use of colors appears to have no impact on short-term or long-term retention of knowledge (23). -Body painting has limited measurable educational benefit over the traditional method of demarcating anatomies using line drawing (23). - Students tend to copy the illustrations in the detailed manual instead of using the reference points (35). - There is risk of emphasizing art too much rather than reliable organ positioning (35). - As this method is fun, it can distract students from educational goals (35).
Technology enhanced, self-directed learning (TEL-SDL) in anatomy	- Virtual interactive anatomy exercises provide learning opportunities for students outside the lecture room that are of especial value to visual and kinesthetic learners (49). - The best use of teacher time is in creating computer-based learning materials and that supplying students with these materials is the most economical way of providing education (29). - Updating digital content is fast and simple. Content can be adapted to the user´s needs. Another potential advantage is cost savings	- Students cannot access expert help during the digital teaching sessions (29). - Depersonalization of medical education and the possible demise of the role of the personally engaged and individually supportive teacher (29). - If online resources have technical problems, students would have to work with outside providers to address any issues to find a solution (38). Preparing the material is rather expensive and time-consuming, and

Anatomy teaching methods	Benefits	Limitations
	because less qualified teachers can be employed to teach students (29). - Software of anatomy is odorless, allowing accessible location of the relevant structures (52). - Self-rotating and multiple-viewing of the image gives dynamism and makes it more attractive to the audience (52). -It can be helpful if used to understand the anatomy of areas of the body in which access through dissection is limited and where functions and spatial relationships are particularly difficult to grasp, e.g., perineum, porto-cava/ cava-cava anastomosis, pterygopalatine fossa, pathway of nerves (105). - It provides a better approach to teaching functional anatomy than traditional methods (105).	special instruments or skills are usually required (52). - Lack of tactile experience (52). - Possible technical difficulties using the programs (52). - Computer skills varied among learners, required plug-ins added complexity to the operating systems of student laptops, the resolution of computer monitors might not be of high enough fidelity for some visuals, copyright and proprietary constraints, and workforce shortages affected software productivity (76).
Educational Virtual Platforms	- They can improve the ability of students to understand some difficult anatomy areas in which access through dissection is limited (105). - Its main feature is the interactivity, this includes immediacy of response, non-sequential access of information, adaptability, feedback options, bi-directional communication and grain-size (76). - The learner is not a passive observer, but instead, a participant engaged in a performance-based activity (76). - Increase in the efficiency and reliability of the assessment process, immediate scoring and feedback for the student and the instructor (106). - Online tools have revolutionized access to detailed, well-documented, easily searchable anatomical data (53). - It actively requires the students´ participation, it focuses on specific problems, it asks students to take responsibility for their own learning (53). The online environment offers distinct advantages regarding image quality,	- Concerns about privacy and security issues and the potential for unprofessional content (15). - Some students prefer to work with printed material and do not like reading material from a computer screen (76). - Some students have reported a problem with the site navigation (76). - Computer skills varied among learners, required plug-ins added complexity to the operating systems of student laptops, and the resolution of computer monitors might not be of high enough fidelity for some visuals (76). - There is a requirement of an initial investment in time and computing resources (93). - Some anatomy websites are lower-quality sites from the didactic point of view. Thus, a site can exist one day and disappear the next (108). - Depends on good internet service; failing servers can disable the student's learning process. Sometimes, there are difficulties with connection (108).

Anatomy teaching methods	Benefits	Limitations
	psychometric analysis of the examination, and reduction of staff preparation time (93). - Online assessment of anatomy has several advantages: time-saving used in setting up the examination in the dissecting room, maintenance of the integrity of cadaveric specimens for longer periods, setting up of an examination bank containing questions with good psychometric parameters, and provision of faster feedback to students on their performance (93). - It provides a large volume of educational material in a single, readily accessible location and permits flexibility in the material format (73,107). - Students can search easily different topic using user-generated key words (107).	- Generating computer-based representations of the whole body is costly and requires institutional commitment (109). - All online anatomy programs lack inference capabilities, requiring inherent intelligence (109). Poorly organized material can negatively affect the efficacy of the educational resource (73).
Social virtual platforms	-The main attraction of social networks is peer interaction, sharing experiences, opinions, concerns and information in a different classroom environment (15,54–56,110). - The use of social networks in an educationally relevant context can improve interactions between faculty and students (15,54). - Ease of access to learning material. Searching for or watching a video on YouTube does not require logging in (15,56,110). - Logging in allows YouTube to suggest related videos based on the previous viewing history (15). YouTube is a readily available, free resource and the software and hardware described are not expensive (15,56). - Visibility of many teachers. YouTube videos can be used in different contexts in other courses and in multiple applications (15). - YouTube can encourage learners to reflect on the material presented in a medical curriculum (15). - YouTube videos and Facebook page are helpful in supporting independent learning	- YouTube is an inadequate source of information for learning surface anatomy (55). - Lack of high-quality educational video clips (55). -There were no videos covering head and face surface anatomy, neck, thorax and abdomen surface anatomy. (55). -Any user-generated content with no quality regulations, rendering such content a source of misinformation. (15). -Searching for appropriate clips on YouTube´s large collection may prove challenging and time-consuming for students (15,56). -Students should be aware of social media´s security and privacy issues ant the potential for unprofessional content (15,54). - The design and creation of videos require extra time and effort by the faculty (15). - The anatomical information in YouTube videos may be misleading due to the absence of content review (56).

Anatomy teaching methods	Benefits	Limitations
	and in enhancing student motivation and engagement (15,54,110). - Facebook could be a suitable learning environment, more interesting and challenging (54). - Facebook is an effective tool in contributing to learning and favoring exam self-confidence; it also provides a formative assessment by providing feedback and peer assessment (54,110). -Facebook may prepare medical students to use more professionally oriented social networking sites for lifelong learning (54). - For collaborative teaching and learning, social networking sites are more convenient and satisfactory for today´s students (54). - Most students are on social networking sites, with a predominance of Facebook (110). - Facebook is inclusive, accessible, time-effective, and cost-effective (110).	- To some, Facebook is more of a distraction than a learning tool (54). - Another negative impact students report is procrastination behavior on their part (54). - Not all students and anatomy teachers have a Facebook account or YouTube channel (54).
Comics trips/ Limmerick	- Comic strips facilitate efficient and effective communication of complex information, disseminates ideas in fun ways (18). - Limerick promotes fact retention and recall and may increasing motivation, interest and/or enjoyment as well as improved comprehension (18,20). - Limmerick can be used to promote active learning by encouraging students to review functional anatomy-based content to create limericks with good learning value (20).	- Labor-intensive and time-consuming (20). - The comic strips were written and drawn by experienced anatomists (18). - The available commercial comic are not ideal, because most cartoonists who write and sketch them have no formal anatomy training (18). - It is desirable that an anatomist simultaneously writes and illustrates the comic strip (18). - Providing pictures to learners does them a disservice, because they are not given a chance to create their own mental images (18). - Expecting learners to imagine accurate mental pictures from verbal descriptions alone is unrealistic (18). - Science comics might misrepresent the actual science (18).
Plasticine/ Clay modeling	- It allows students to learn the deeper muscles first and build on to them. Students can gain an appreciation of various muscles' grouping, synergism, and antagonism, and it	- Clay modeling is not an effective learning technique for long-term retention of knowledge about sectional anatomy (39).

Anatomy teaching methods	Benefits	Limitations
	helps them understand cross-sectional anatomy (21,39,58). - Plasticine modeling is an excellent vehicle for demonstrating the metacognitive process that enables self-regulation (a known predictor of academic success) (58). - Plasticine modeling experience is non-threatening, fun, and exploits different learning styles (58). - Clay modeling has improved students' understanding of cross-sectional anatomy (20). - Clay modeling can be applied to any human body part (39). - Using modeling clay presented no economic burden, allowing all students to retain the models they had made (39). - Clay modeling will be even more helpful in cases of more complicated cross-sectional anatomy, such as the muscular system in the shoulder joint (39). - After the polymer clay is converted to rubber, it can be kept for years without deteriorating, and thus, the model may serve as a continued source of reference (39).	- Plasticine modeling has the acknowledged limitations of no direct retention and assessment data (58). With clay modeling of muscles, students cannot see how muscles are wrapped in fascia, aponeuroses, and various structural features (21).
Yoga and Pilates	- Enhance physical awareness, nontraditional learning environment, increased anatomy comprehension, relaxing and fun qualities (16). - Incorporates auditory, visual, and kinesthetic elements (16).	- Limited to specific anatomical themes: muscle function, innervations, attachment and location, muscle and bony landmark palpation, and clinical correlates (16).

6. ***Anatomy in the living body: radiological imaging.***

Radiology education, such as radiographic, ultrasound, CT, and MR images, offers in vivo visualization of anatomy and physiology and insight into pathological processes (12,37,38–41). Common methods to integrate radiology with anatomy instruction include concurrent radiology lectures, small group learning with and without formal instructors, and radiologic images of de-identified patients in the dissection laboratory (42).

7. ***Anatomy in the living body: observation of surgeries.***

The sixteenth and seventeenth centuries operation theaters were created as the first amphitheaters of anatomy, initially intended for surgical demonstrations, dramatized

rather than to teach anatomy. These procedures were also known as “theatre operations, “subsequently, due to the need to train surgeons, the theatres acquired educational functions and became surgical amphitheaters (43,44). Nowadays, operating theatres are a challenging place to learn, especially for medical residents, and this learning potential may be realized through curricular initiatives (45).

8. ***Anatomy in the living body: body painting or drawing***.

Painting internal structures on the body's surface can be effectively used with palpation and auscultation (23,31,35). Students find it a highly memorable experience that leaves them with strong visual memories and a heightened appreciation of the links between visual, tactile, and auditory aspects of human anatomy (46).

9. ***Technology-enhanced, self-directed learning (TEL-SDL) in anatomy***

Among the basic sciences, gross anatomy represents a unique opportunity for incorporating technology and electronic dissemination of information because of the visual nature of the course material (38). Some teachers have integrated technology into anatomy teaching in different forms or variants (29,38, 47–49). Technology-enhanced learning through didactic resources like the anatomical commercial packages (50,51) and numerous free and commercial apps (10) can be particularly successful when the teaching content and exemplars are predominantly visual (29).

10. ***Educational Virtual Platforms***

In educational platforms, also called the Learning Management System (LMS) or Virtual Learning Environment (VLE), interactivity is an essential element in instructional design, as it serves learner interest, cognitive processing, and curriculum integration (52,53). Allen et al. report on the implementation of a website called ARI (Anatomy Reports on the Internet), allowing students to document cadaveric findings online with photographs and text, providing an opportunity for medical students to research, describe, and publish their findings, albeit in a limited format (53).

11. ***Social virtual platforms***

Facebook and YouTube invite users to actively participate in content creation and editing through open collaboration between members of communities of practice (collaborative learning) (15,54,55). One study showed the use of Facebook to supplement traditional anatomy education as an appropriate instructional tool; they found that 94% of the students rated the page as very good or excellent; in addition, the page was perceived by 89% of students to be effective in contributing to their learning experience (54). Some authors believe that, considering YouTube’s popularity, it should be regarded as an effective tool to enhance anatomy instruction if the videos are scrutinized, diversified, and aimed toward course objectives (15,56). However, there is no consensus in the literature (55).

Miscellaneous

Some have explored unconventional methods, such as 12) Comics trips/Limmerick (20,57), 13) Yoga & Pilates (16), and 14) Plasticine/clay modeling (21,39,58). In such cases, “fun” is one feature they have in common, but they can also be helpful for students who prefer a kinesthetic learning style. However, these methods are limited to studying a single system (muscle), as in the case of yoga & Pilates and clay modeling (16,21).

Table 3 summarizes the benefits and limitations of these 12 anatomical teaching methods and Mayer’s educational principles.

Table 3: Comparison Of Anatomical Teaching Methods On Aspects Of Feasibility And Proven Instructional Design Principles

Anatomical teaching methods	Operational feasibility			Technical feasibility	Economical feasibility	Attends to Mayer principles of instruction (see Methods section)								
	Organizational	Infra-structure	Time			1	2	3	4	5	6	7	8	9
1. Lecture	+++	(-)	++	++	+++		+				+		+	+
2. Dissection	(-)	(-) (-)	(-) (-) (-)	(-) (-) (-)	(-) (-) (-)	+		+	+	+		+		
3. Prosection/Plastination/ Plastic models	+++	(-) (-)	(-)	(-) (-)	(-) (-) (-)	+	+	+	+	+		+		
4. PBL	(-) (-)	(-) (-)	+++	(-) (-)	++		+			+	+		+	+
5. Physical examination	(-)	(-) (-)	++	(-)	++		+		+	+	+		+	+
6. Radiological imaging	+++	(-)	+++	(-)	(-) (-)		+	+	+	+		+		
7. Surgery/OR	(-) (-)	(-) (-)	(-)	(-) (-)	(-) (-) (-)		+	+	+		+		+	+
8. Body painting	(-)	(-)	+	(-)	+		+		+	+	+		+	+
9. Technology Enhanced Learning	++	++	++	(-) (-)	(-) (-)	+	+	+		+	+	+	+	+
10. Educational virtual platforms	++	++	Design (-) Execution ++	(-) (-)	+	+	+	+		+	+	+	+	+
11. Social virtual platforms	(-)	++	(-) (-)	(-)	+		+	+		+	+	+		+
12. Comics trips/Limerick	(-) (-)	+++	(-)	(-) (-) (-)	(-)		+	+	+	+		+		
13. Plasticine/Clay modeling	(-)	(-)	+	(-)	+		+		+	+		+	+	
14. Yoga/Pilates	(-) (-) (-)	(-) (-)	+	(-) (-)(-)	(-) (-)		+				+		+	+

6.6 Discussion

When selecting strategies, we must consider the type of content and skills to be developed; as we have seen, not all methods are suitable for teaching and learning all content (conceptual, procedural, and attitudinal) and skills (cognitive, psychomotor, psycho-affective, and communication). Anatomy needs strategies that develop conceptual and procedural content and cognitive and psychomotor skills for its theoretical and practical nature.

Our literature review revealed fourteen distinct approaches to the teaching and learning of anatomy. Of those 14 different approaches, we specifically evaluated their feasibility for low- and middle-income countries (LMIC) and classified this feasibility (conceptual, economic, operational, and technical). Different approaches to teaching and learning experiences in anatomy are driven by many factors and perceptions, e.g., the curriculum, assessment, previous educational experience, and the influence of staff and fellow students. Not all anatomy faculty have had appropriate training in dissection techniques, radiological image reading, teaching methodology, or computer skills (25,59,60). Anatomy teachers are usually medical doctors, senior medical students, or recently graduated doctors who serve as teaching assistants. Some aim primarily at gaining work experience or securing a temporary income and do not feel much passion for teaching anatomy. This may affect education, as the quality may not be optimal when teachers do not fully understand or do not enjoy what they teach. The motivation of faculty affects the motivation of students (61).

Dissection and prosection remain helpful in understanding the three-dimensionality of the human body and the haptic perception, distinguishing the texture of the body's different tissues (4,5,25,30,46,62). However, its expenses are clear limitations, given the high costs of transportation, maintenance, and the disposal of corpses (4,25,36,59,63–65). These and other limitations, such as safety risks due to the exposure to formaldehyde (36,38,59,66) and the time-consuming nature (67), make prosection and dissection operationally, technically, and economically unfeasible methods in LMIC.

While PBL is known to stimulate retention and acquisition of basic science knowledge (27), inadequate resources are often a limitation; it requires faculty training on PBL facilitation and adequate infrastructure to assist small groups (68), making it an operationally and technically less feasible method in LMIC. PBL was not initially designed to acquire basic science knowledge and is generally believed to be more suitable for clinical knowledge (69).

Radiological imaging helps make the knowledge of gross anatomy more practical and applicable, as radiology is rapidly expanding as a medical domain to represent the body in numerous ways (42,70) visually. However, it only meets 5 of 9 Mayer´s principles, and its economic and technical capabilities are not optimal. Many anatomy

departments may not be large enough to purchase facilities for ultrasound, CT, or MRI (71) and have trained staff to use these (72).

Online tools can be very attractive for current generations of students and help increase interest in a complex topic such as gross anatomy (73,74). Online learning is reported to be as effective as traditional methods in training health professionals, yielding retention of skills and knowledge up to 25% more than conventional methods (75). However, computer skills vary among learners, and technical difficulties may exist when using the programs or platforms (52,76). Despite these risks, specifically for LMIC, if adequate technical support staff lacks, its operational feasibility is one of the most appropriate, providing learners with content and interaction anytime and anywhere (77).

Mayer´s principles are most found in signaling and segmenting. These principles go hand in hand and complement each other since anatomy can be studied segmented, addressing only one anatomical system or region (segmenting). It keeps students focused on the task by highlighting essential information (signaling). (Table 2)

The literature highlights the successes of several approaches in the teaching of anatomy used so far. Therefore, an eclectic model means combining complementary strategies, which could be the better way of teaching and the key to meeting the curricular changes and the current needs of teaching and learning for better understanding, retention, and application of anatomical knowledge (72,78,79). For example, at the beginning of an anatomy course, traditional strategies such as lectures can be used to give a general orientation of the topic to study. Next, innovative approaches such as VLE for self-study sessions with a study guide and homework and easy clarifying doubts using academic chat are also available. In the end, it can be practical classes in 2 phases: the first one, traditional with models and prosected specimens, and the second one, innovative with radiological imaging and CAL. That way, the anatomy is studied in the dead (specimens/cadavers prosected) and in vivo (use of imaging), emphasizing self-directed learning. However, these methods are not helpful without a proper instructional design and well-trained anatomy teachers (4).

Our review was set out to yield recommendations for anatomy teaching in resource-deprived countries. If viewed from the perspective of educational principles, combined with the feasibility of execution, technology-enhanced learning and educational platform methods seem most promising. However, it´s important to remember that, despite the many benefits of technology in teaching anatomy, “the most important thing in e-learning is not the technology, it´s the teaching” (80). An aspect to consider is the pre-training principle for both students and teachers; these methods need training in using them (platform or software), designing an online course, and professional staff who manage the educational platforms. In addition, it´s essential to have constant electrical power and a good and fast internet service, which in resources-deprived countries frequently fail (81). Not all these are economically and technically

optimal, but it is expected that the economic and technical cost for their optimization will decrease as the initial investments may serve many generations of students; in addition, compared to the price of the maintenance that entails dissection, Technology Enhanced Learning and Learning Management System are cheaper in the long term.

6.7 References

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CHAPTER 7

ANATOMY EDUCATION IN LOW-RESOURCED COUNTRIES: WHAT ARE CHALLENGES AND EFFECTIVE AND AFFORDABLE EDUCATIONAL STRATEGIES?

This chapter has been submitted as follows:

Chang Chan, Ana Yoe Cheng; van Leeuwen, Maarten Simon; Custers, Eugene; Bleys, Ronald; ten Cate, Olle. Anatomy Education in Low-Resourced Countries: What Are Challenges and Effective and Affordable Educational Strategies?

Author contributions:

Conception of the study:	AYCC and OtC
Data collection:	AYCC
Data analysis:	AYCC, RLAWB, EHFMC, MSvL, OtC
Writing the first version of the manuscript:	AYCC
Critical review and adding import intellectual content:	RLAWB, EHFMC, MSvL, OtC

All authors consented to the final version before submission to the journal.

7.1 Abstract

Purpose. With limited means, resource-deprived countries must find ways to organize education creatively to meet standards. There are few reports about studies on anatomical education in LLMIC. This study explores how anatomy teaching is sustained in countries with few resources and what affordable educational strategies are applied to uphold quality.

Methods. A mixed-method study with anatomy teachers from public medical schools in Africa, Asia, Europe, and Latin-American was performed through a survey via email (n=13) combined with a semi-structured online interview (n=8) with teachers from Zimbabwe, Mozambique, Pakistan, India, Venezuela, and Nicaragua, to explore survey at more profound.

Results. Significant teaching challenges LLMICs face, primarily due to lack of funds, are faculty shortage (low salaries and high student-to-teacher ratio) and inadequate infrastructure (internet, electricity, and poor classroom conditions). Solutions were associated with didactic strategies (e-learning, image-based learning, and applied anatomy), expanding teaching capacity with less qualified and part-time faculty, student-organized education, and self-financing (teaching resources subsidized by teachers and students). Striking was teacher commitment despite difficult circumstances. Their desires and proposals regarded better faculty management, increased anatomy staff recruitment, and collaboration with other institutions.

Conclusions. Anatomical education in LLMIC is forced to adapt to the socio-economic context, not so much to trends in medical education worldwide. These adaptations are supported mainly by the teachers ‘commitment.

Practice points.

- Reports about educational solutions from affluent countries dominate the Health Professions Education (HPE) literature.
- Anatomy education, inherently expensive in low-resourced countries, must creatively find ways to cope with limitations.
- Primary challenges include faculty shortage, low salaries, and inappropriate infrastructure requiring tactical and strategic action levels.
- Creative but palliative adaptations at the operational level on anatomy teachers´ commitment and the subsidy fueled by teachers and students.
- U-learning, image-based learning, and applied anatomy are viable didactic strategies for LLMICs.

7.2 Introduction

Population health and education are priorities #3 and #4 on the 17 United Nations Sustainable Development Goals (1). Medical education aims to improve the population's health through education, irrespective of race, wealth, and geographical location (2,3), and requires resources and quality standards. However, the World Bank lists 82 of the 197 countries of the United Nations (42%) as low-or-lower-middle-income countries (LLMICs). To achieve global standards in medical education, quality assurance has gained strength in recent years through multiple international collaborations, such as the World Federation for Medical Education and FAIMER (4). To meet these standards and uphold teaching quality with limited resources, medical education in LLMICs must find ways to organize education creatively. Sharing information on teaching and assessment methods internationally is essential to facilitate this process.

The information exchange is predominantly unidirectional: the Global South* [1]learns from the Global North, and virtually all commonly shared medical education advances in journals and conferences stem from studies and publications in Western countries (i.e., the Global North) (5). However, low-resourced countries have their own stories and may develop unique solutions to share with the more affluent nations.

Currently, only a limited number of studies related to medical education consider the context of LLMIC (5,6) and describe how these countries manage their limitations to uphold quality education.

Our study explores how medical education, traditionally considered cost-intensive because of plastic models and the potential use of donated bodies, is executed in countries with low resources. We focused this study on anatomy education, as anatomy is regarded as a pillar of medical curricula and requires substantial resources. An accurate understanding of human anatomy is essential for safe clinical practice, irrespective of country and culture (7,8); knowledge belongs to the canon of medical competence (9). Using prosection and dissection of human bodies in anatomy teaching is valuable, but the required infrastructure and personnel support involves high costs and is therefore not always feasible in LLMIC (8,10,11).

The evolution of medical curricula in Western countries over the past half-century has considerably impacted anatomy, especially in proportional curricular time devoted to anatomy education, which has decreased dramatically worldwide due to the increase of other curriculum components (12,13), and costly technological advances are changing its nature. Consequently, time-and-cost-efficient educational methods are needed, particularly in LLMICs.

* There is a dispute about the terminologies of Global South and Global North. We adhere to original UNCTAD definitions.

Our research aims to explore how anatomy teaching quality is sustained in countries with few resources and what practical and affordable educational strategies are applied to uphold quality. More information on this domain is needed in the literature. More specifically, we were interested in the following questions:

- What are the challenges for anatomy education in public medical schools of LLMICs?
- How do public medical schools in LLMICs deal with limitations in teaching anatomy in the medical curriculum?
- What can schools learn from each other´s creative initiatives to preserve quality education under low-resource circumstances?

Exploring and reporting the conditions and solutions for anatomy teaching in these countries will likely benefit other institutions in LLMICs but may also open eyes in more affluent countries. Anatomy education faces many challenges in medical schools worldwide, including climate change, warfare, and migration disasters that affect economies. However, the increased need for trained health professionals requires more facilities for anatomy teaching. They may be overcome by creating awareness, finding the best way to provide quality anatomy education under challenging circumstances, and facilitating international collaborations with and between LLMICs.

7.3 Methods

Design

Our study uses an explanatory mixed methods design (14) using a survey followed by semi-structured interviews based on the survey items.
The focus is on anatomy teachers in public medical schools in LLMICs.

Population and sampling

Potential respondents were sought by approaching contact persons of relevant public medical schools using the World Bank´s list of LLMIC and email addresses as provided in the World Directory of Medical Schools (15). Using a snowball technique, these contact persons were requested to facilitate the contact of an anatomy teacher in their institutions as potential participants in our study and provide their email addresses supplemented by international contacts from the authors´ networks (AYCC, RB, and OtC).

Data collection

Phase 1. The Survey

A questionnaire was created (by AYCC and OtC) and pilot-tested using cognitive online interviews (16) via Zoom.us® with eligible anatomy teachers from countries on different continents (Nicaragua, Malaysia, and South Africa). The improved questionnaire and a letter of invitation, with versions in English, Spanish, and French

(appendix 1 and 2), were distributed using the available contact email addresses (n=13) in LLMIC with a reminder after two weeks.

We used a Word document, providing space for brief or extended answers depending on the question. We did not employ an electronic survey tool. We created individualized versions of the questionnaire in the language of each respondent (using Google Translate) and allowed them to respond in their language. The questionnaire included informed consent, data about the school and curriculum, the number of students and anatomy teachers, budget, curriculum hours of teaching in lectures, dissection labs, or other educational activities. Next, questions were asked about students' knowledge of anatomy at graduation, satisfaction with anatomy teaching conditions, components highly valued in one's anatomy training, and elements that could be improved if additional resources were available.

Phase 2: The interview

All survey respondents were invited for an online explanatory interview to discuss the topics, challenges, and strategies to deal with existing limitations of anatomy education more deeply.

One researcher (AYCC) conducted all interviews using semi-structured interview guide questions based on participants' survey answers and considering the study's research questions. All interviews were recorded and held in Spanish or English, which proved sufficient to allow all respondents to participate. Transcripts of all interviews were created with the help of Otter.ai® or Sonix.ai®, and AYCC made subsequent corrections.

Analysis

We used thematic analysis (17) with a phenomenological approach, which emphasizes the study of conscious, lived experiences to understand the reality around the involved participants, taking their personal experiences as a source of knowledge (18).

The transcript analysis sought to identify the unit of study. Each transcript was initially reviewed, after which text fragments were identified and labeled with initial codes. After initial coding, themes were determined as most frequently occurring, relating to several initial codes. AYCC generated initial codes and searched for themes for all transcripts, and MvL, EC, and OtC did the same, in parallel, for samples of 2 or 3 transcripts.

AYCC merged the analyses and added codes into the themes and their sub-themes.

Ethics

Ethical approval was sought from the Netherlands Association for Medical Education Ethical Review Board. While this Board could not provide formal approval

because no participants were from the Netherlands, it delivered a general review of the research protocol with comments.

To justify meeting ethical standards, we followed recommendations for reporting ethical approval for studies involving human participants without access to formal ethical approval (19). All participants were informed about the procedure in detail and supplied informed consent. While the issues discussed were non-sensitive or harmful, we noticed hesitations in expressing politically sensitive opinions in a few cases. We guaranteed that published results would not be traceable to individuals and that data storage and use were explained.

All information received from participants was treated confidentially and shared only within the research team. The research report only revealed respondent or institutional information if relevant to the study report and with the respondent's consent.

7.4 Results

From the invitations sent to 82 deans of public medical schools, for whom contact information was available through the World Directory of Medical Schools, supplemented with the research team's personal network contacts, we identified 13 anatomy teachers from four continents (Asia, Africa, Europe, and America) willing to complete the questionnaire. From these groups, we organized eight interviews with anatomy teachers in LLMICs (Africa, Asia, and Latin America).

Table 1: Continents and countries with study participants

Latin America	Africa	Asia	Europe
Countries with anatomy teachers who completed the questionnaire			
Nicaragua	Mozambique	Malaysia	Moldova
Argentina	South Africa	India (2 participants)	Georgia
Venezuela (2 participants)	Zimbabwe	Pakistan	
Countries with anatomy teachers who participated in the interview study			
Nicaragua	Mozambique	India (2 participants)	
Venezuela (2 participants)	Zimbabwe	Pakistan	

Through thematic analysis and constant comparison analysis of the transcripts, we defined two broad thematic categories (“problems” and “solutions”) and three large subcategories for the latter (“implemented solutions,” “suggested solutions,” and “aspirational but not realistic solutions”), each with a series of more detailed subthemes.

Problems

We identified six subthemes in the category of problems.

Table 2: Main survey outcomes

Item	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
Number of medical students enrolled each year	290	80	188	350	100	400	900	300	140	240	1200	64	1400
Full-time anatomy teachers	4	6	23	3	2	6	18	3	7	7	35	2	21
Available anatomy teachers	4	6	16	8	2	8	26	12	8	7	20	1	23
Student-to-(available) teacher ratio	72.5	13.3	11.75	43.75	50	50	34.61	25	17.5	34.28	60	64	60.86
Student-teaching assistants	0	0	0	3	1	2	8	0	0	10	5	0	7
Anat teachers with a medical degree	4	5	23	6	2	8	18	12	2	5	15	1	32
Anat teachers with postgraduate training	2	2	15	4	3	6	18	3	6	7	9	2	21
Number of years of anatomy in medical curriculum	3	2	1	2	1	1	1	2	2	4	3	3	4
Contact hours of lecture	70	66	150	84	220	approx 240	approx 160	230	approx 80	86	114	30	80
Contact hours of dissection	0	0	350	172	415	0	approx 80	160	approx 360	0	70	0	30
Contact hours of demonstration or practical class	96	260	150	86		aprox 160	aprox 80	124	aprox 80	90	330	37	100
Contact hour other teaching approaches	0	0	50	0		0	aprox 320	0	0	0	330	9	120
Group size (number of students) in Lectures	290	96	188	350	100	40	40	50	140	240	110	64	15
Group size (number of students) in dissection	0	0	18 per table	350	50	0	40	50	70	0	12 per table	0	7.5
Group size (number of students) in demonstration or practical class	40	30	45	350		40	40	50	70	10	12	16	55
Group size (number of students) in other teaching approaches	0	0	60	0		0	40	50	0	0	12	16	60

*Anatomy staff constraints***.** Faculty shortage appeared to be a constant across the interviews. All schools suffered from high student-to-teacher ratios, often caused by increased student enrolment without an increase in anatomy teachers, heavy teaching workloads, and frequent repetition of teaching for large groups, with little space for preparation, innovation, and personal development. In vacancies, it appeared hard to attract new faculty because of low salaries. Several teachers reported being on the verge of burnout.

Environmental and contextual limitations. Several participants mentioned their countries´ economic (inflation, expensive gas, low salaries) and socio-political (vandalism, unsafety, limited freedom of expression) situations, leading teachers and students to leave their countries. Another constraint was the consequences of COVID-19, related to the difficulty of obtaining corpses and fostering contactless teaching.

Lack of project funding. Institutions generally had no budget for research projects on anatomy, such as pure science and minors for anatomy education, because the funds were often destined for projects at hospitals or related to public health.

Lack of didactic resources. A recurrent topic was the need for more plastic models, cadaveric material, and microscopes geared to the number of students and the difficulty in acquiring these, especially corpses. The technological resources' limitations mentioned as missing were laptops and data projectors, a learning management system (LMS), and anatomy software to support teaching. Several institutions suffered from poor conditions of teaching facilities, being damaged or nonfunctional.

Inappropriate infrastructure. Anatomy teachers were concerned about internet problems, conditions, and available spaces. As for internet problems, they mentioned unstable connections, poor service by the university, and disconnection due to payment issues. Conditional constraints included electrical energy problems, acclimatization, lighting, and furniture. Regarding spaces, teachers mentioned small classrooms and halls for the many students they receive.

*Curriculum deficiencies***.** The most frequently mentioned topic was related to the content of programs, where teachers felt a need for more time for crucial morphological domains (embryology, histology, neuroanatomy) and an information overload for students. Another recurrent theme was more faculty development and teacher educational support. Substandard assessment and discordance between systemic (in the curriculum) and topographic (as covered in books) approaches were also mentioned.

Because of these challenging situations, some participants noted anatomy teachers´ demotivation, which affected innovation and creativity. (Table 3)

Table 3: Theme: Problems

Subtheme	Codes	Quotes
Anatomy staff	Student-teacher ratio Low salaries Heavy workload Not Qualified Demotivation	- *"…We have 100 students together with us weekly. There are two corpses where dissection is happening simultaneously. So, 50 students on one teacher… in this scenario, would you be able to do it* (innovation)? *I will say no. Neither do I have many faculty in the department, nor is the motivation there … not every teacher is motivated to work…"* (Participant 5). - "*… I must calculate, is my rent paid? Is my mortgage paid? Is my grocery bill Okay? Those decisions will tell me, " I need to do some clinical extra service in private." It's not for making money. I think the economic situation of the country sort of forces those people to make choices, and anatomy is not high on the option because of the remuneration. And even when I have people interested in anatomy, they would never be able to make a living with our local salary… I don't know about creativity. We've stopped doing it creatively. It drains you when you're in such an environment to be creative and think outside the box; it's tough…we would never get funding for such a project*" (Participant 4). - *"… you also have these kinds of responsibilities, which are very important... like hospital management, some problems with curriculum or this committee that you are taking time from teaching activities and focusing on them, it's the same constraint..."* (Participant 8). - "…d*ue to the heavy workload in teaching hours, we do not have a training plan*" (Participant 1).
Environment /context	Economic and socio-political situation Consequences of COVID-19	- *"… because of our economic situation… what's happening in my country is much drama. Most doctors and people with medical degrees would prefer to either leave the country once they've completed and not go back into teaching or go into private... people who have stayed behind remained for some other reason, let's say you have a sick relative… and need to make extra money from a part-time job" (Participant 4).* - *"… and vandalism… they took everything and didn't even leave the roof or the loose cables in those areas... everything was stolen: cadavers, the brain samples, the lung samples, the anatomical pieces. We can't do any practice..." (Participant 6).* - *"The government has removed any anonymous feedback… it always boils down to punishing the person who has raised their voice. I can freely talk to you because you would respect my anonymity. Because if my name comes out, I know I will be punished in my colleges for speaking on so many things that will not be accessible" (Participant 5).* - *"… It's been days since COVID started, and we're starting not to receive bodies… COVID created a problem of mental laziness because, for two years, we were teaching classes with a computer... After COVID, we had students with little desire to study…" (Participant 2).*
Lack of funding	For research projects For teaching resources Lack of personnel	- *"I started much research but can't do everything because I also don't have a budget… My faculty has many projects, but all of them are about public health, Malaria, or AIDS. And if you are looking for a scholarship, if you are not doing a study on malaria and AIDS, they will not give you a scholarship" (Participant 2).* - *"… we do not have all the elements to preserve corpses properly, which has caused them not to be used 100%. They are dehydrated for fear of fungus and damaging the structures…" (Participant 1)* - *"Since the universities are autonomous, accessing private security personnel and hiring personnel isn't easy… there is a deficit of labor and security personnel" (Participant 7).*
Didactic resources	Insufficient Difficulty acquiring	- *"… we have to make more groups with so many students and don't have the models, specimens, or banners for all the groups…" (Participant 1)*

Subtheme	Codes	Quotes
	Technological resources limitations	- *"…we don't have much access to plastic models… we are mainly using them for postgraduate and super specialty training, not undergraduate medical education" (Participant 3).* - *"There are no computers or digitalization in the lecture theatres. We do not have simple recorders or projections. Can you imagine? We do not have a learning management system"* (Participant 5). - *"…some of the old models are available, but broken and remain few but not in good condition… how can we say enough if they're not working? They're old. I mean, the number is acceptable, but quality…" (Participant 8)*
	Poor condition	
Infrastructure	Internet	- *"… we don't always have Internet. So I better work from home. I am paying for the Internet, but it is difficult for the faculty. Look, other disciplines have a whole technology, but anatomy has nothing... Anatomy has everything terrible"* (Participant 2). - *"We have scheduled and unscheduled outages. We have had a full day without power" (Participant 6).* - *"… there are spaces; they are there, but they are disabled, deteriorated."* (Participant 7).
	Conditions	
	Spaces	
Curriculum deficiencies	Content of anatomy programs	- *"… there is a gap between what we teach and what they need to do. So, this gap is the one area where we need to advance or incorporate this change into the curriculum... anatomy as a subject is very information-dense; we have many things to memorize..." (Participant 5).* - *"The amount of neuroanatomy time required to teach is a minimum of 20 to 25 hours, but we have only 15 hours. …In addition, the lack of time available for embryology teaching… Another problem is that the assessment standards have been diluted; it's tough because assessing 200 students with only two teachers in a single goal will always be difficult..."* (Participant 3). - *"...I don't know whether the changes are good or bad, there is no backup or support for teaching, teaching how to teach..."* (Participant 4). - *"The integrated curriculum is system-based, but all the books written are region-based anatomy books...So, information is chunked in different chapters..."* (Participant 8)
	Methodological support	
	Quality of assessment	
	Discordance between systemic and topographic approaches	

Solutions

The actions anatomy teachers have implemented to face anatomy constraints can be grouped into four subthemes.

Didactic strategies

Location-independent learning (ubiquitous learning). A recurrent didactic strategy to deal with faculty shortage and lack of teaching resources includes computer-assisted learning (CAL), mobile (m-learning), and online learning. Regarding CAL, the use of videos was habitual, whether made by the teachers or taken from YouTube. Concerning mobile learning, interviewees mentioned using messaging apps (WhatsApp, Telegram) to communicate, discuss clinical cases, clarify doubts, back up information, and share study material (documents, videos) and assessments (Google forms). Respondents referred mainly to virtual meetings, assessments, gamification, and LMS for online learning.

Image-based learning. Rather than oral and text-based, another recurrent didactic strategy to deal with corpses and model scarcity was drawing and coloring as the primary means used during lectures or self-study to facilitate understanding of anatomy subjects. In addition, they use less text and more images and diagrams, either in an atlas book during practical classes as pictures and diagrams during assessments or in study guides.

Applied anatomy. Another prominent strategy used to motivate, engage, and build up elements for learning. It was clinical correlation during lectures, early clinical exposure, radiological anatomy, and, to some extent, surgery observation.

Project-based learning. Less frequently mentioned than the previous strategies, where students made anatomical models and posters using team-based learning and performed oral exposures during practical classes. Most self-made anatomical models used clay or bookstore materials.

Extracurricular activities. Some students were encouraged to participate in extracurricular anatomy research projects and asked to attend scientific conferences and theoretical-practical courses developed by the students' societies.

Anatomy teacher attributes

All participants suggested implicit solutions related to the teacher attributes in response to the problem of low wages and heavy workloads. The most recurrent was the teacher´s commitment, which implies motivating students, recommending a bibliography, and being a student role model.

Intrinsic motivation and teaching models were also constant. Teachers were upholding quality because of their passion for teaching and the satisfaction of working

with student learning. The teaching model included moving to understanding anatomy instead of memorizing structures and allowing students to learn from mistakes.

Employment of less qualified teachers was also mentioned, but less often, because fewer seemed to have appropriate anatomical, scientific, and methodological training.

Another feature to deal with low salaries was teaching part-time, supplemented with other day jobs.

Alternative facilities

To face the faculty shortage, lack of teaching resources, and environmental constraints, the actions mentioned were those used by developed countries, such as dividing the group into subgroups, rotation of teachers, and support from teaching assistants (Ph.D., master, and senior students).

Other strategies include rotation of teaching materials, support from different entities such as the medical skills department or Veterinary Faculty, rescheduling teaching activities (adjusting to the availability of electricity or outside of business hours), and other teaching locations when suitable classroom infrastructure lacking like hospitals and teaching as community service.

Self-financing

To alleviate the lack of teaching resources, teachers and students used their own money for some of these resources when the institution did not provide them. Teachers mentioned using their own electronic devices (personal laptops, smartphones, tablets) for practical classes and lectures; students would rent data projectors for lectures, and both use their internet data for synchronous online activities. Other resources paid for by teachers, sometimes in foreign currency, were student photocopies, laminated images, or printed atlas for practical classes. Some participants would pay for transport to teach when classrooms were in different buildings or cities and distances were significant. One participant mentioned the practice by med students of desecrating cemeteries to get real bones, mainly skulls, as personal teaching resources. (Table 4).

Table 4: Theme: Solutions, Category: Implemented strategies.

Subtheme	Codes	Quotes
Didactic strategies	Ubiquitous learning Image-based learning Applied anatomy Project-based learning Others: scientific conferences, extracurricular activities	- *"We opened a WhatsApp group and are communicating and coordinating there. We use Telegram sometimes. The last time, I left all the classes on Telegram because we had problems with the light… we asked questions and clarified our doubts... we used those videos, watched them, and went on a discussion of topics... The online part is our most handy tool… Also, the anatomical models; they (students) make their oral exposition with those anatomical models... They made them with the materials that we can find in the bookstore. That has worked for me" (Participant 6).* - *"… I have a student who has a knee injury, So I gave him the practical classes through virtuality, and I even gave him the practical exam through a video call. But in the case of conferences, it is established that they have to be virtual… I have also been using, as a form of self-study, the coloring books of Netter and Sobotta… We use many images if we do not have corpses in good condition. In my case, I print images; I use atlases of anatomical dissections… We have also worked on making graphic organizers because students only want to use a book and, based on that, do much memory instead of understanding anatomy" (Participant 1).* - *"…senior teachers prepare these videos, so the junior teachers and students can also see them, and sometimes we take videos from YouTube and then share them with the students..."* (Participant 8). - *"My PowerPoint has many drawings but very little text. When I teach class, I draw and outline an illustration, and each student does it. I look at each student to see if they are making the diagrams. It does not matter whether the drawings are good or bad; they must understand by making some drawings. The tests are also done with figures because it is not always possible to carry out tests with a corpse" (Participant 2).* - *"We also often organized visits to the hospital during our lecture sessions. So, they used to get motivated to interact with patients of those cases we studied in the classroom. These things help many students correlate what they're learning. You could use a clinical case scenario in the classroom and keep discussing" (Participant 5)* - *"Some were extremely useful for me, such as radiological anatomy and clinical reasoning. The class will be more clinically oriented…, and students' curiosity to learn anatomy will increase" (Participant 3).* - *"The classes were moved to the scientific conference. Each teacher from different disciplines gave a lecture within the scientific conference program and then discussed it in class the following week… We also develop many extracurricular activities; for example, several scientific societies develop theoretical-practical courses applying human anatomy." (Participant 7).*
Anatomy teachers	Commitment Intrinsic motivation Teaching models Qualified teachers Part-time job	- *" I don't know the future, but we teachers must keep improving" (Participant 6).* - *"So, they need to understand that one also learns from mistakes…Nothing is more comforting than seeing the student's progress ... The truth is that when you do the things you are passionate about and love, you manage it" (Participant 1).* - *"… before starting to teach classes, I took a master's degree in Higher Education. I understood that adult education is more about going from being a teacher-instructor to being a facilitator, involving and respecting each student's... One of the motivations is to improve from a teaching position" (Participant 7).* - *"…oh, yes. It's so dusty. So, we need to do that. So, it's more of a self-commitment one"* (Participant 3). - *"… they need to make extra money from a part-time job… You cannot be purely one thing; it doesn't work. So, the issue with anatomy in my country is that people don't view it as something you can profit from in private…" (Participant 4).*
Organization/ Management	Dividing the group Rotation of teachers and teaching materials	- *"… it was divided into blocks, each into subgroups of 50 students. During practical classes, they take turns, or what we do is rotate, as we divide into five subgroups during the practical class. We turn the models or banners… Besides, we have been supported by professors from other areas, mainly medical skills... Sometimes, we have had to reschedule, suspend, or find another way of learning because the power goes out"* (Participant 1) - *"We use our MSc anatomy and bachelor's degree students; they are supposed to make models from the corpses and be demonstrators for the younger students. So far, using students has been the most successful. Unfortunately, students cannot*

Subtheme	Codes	Quotes
	Teaching assistants	*choose... In addition, clinicians come to teach parts of clinical correlates... Another way is community service; suppose somebody has gotten into trouble with the Medical and Dental Council, they're under surveillance, and the penalty will be something like doing community service, so they must do 100 hours unpaid; we get many people who are forced to come and teach."* (Participant 4). - *"Sometimes, we take the students to the hospital, gather them in a room, and do the evaluations there because we are in a better area."* (Participant 6).
	Collaboration	
	Other (rescheduling activities, different teaching scenarios, community services)	
Self-financing	Technological resources	- *"… with audiovisual media, the students rent the data projector out of their own pockets; that way, we can project the classes in the classroom. I use my laptop… So it would be different if the University provided it to me…"* (Participant 6). - *"… but it costs money to laminate them because you have to do color printing, and the department does not have a color printer. Then, you have to laminate it and pay in foreign currency. You're going to take your own money and photocopy the books… Also, if I travel down to the National University, which is about 400 kilometers from where I live, I will teach a block, then return and continue with these medical students. So if you must travel to teach, you must pay, and the gas is expensive."* (Participant4). - *"Desecrating cemeteries... some classmates went to the cemetery and, well, they made use of a skull while negotiating with some gravedigger—desecrating graves... As a student, I inherited a skull from my family"* (Participant 7).
	Teaching materials	
	Transport to go to teach	
	Desecrating graves	

Realistic suggestions for solutions

Based on their experience and context, interviewees generated proposals and ideas for addressing the constraints of anatomy education in LLMICs.

Faculty management

Participants recommended three spheres of action that authorities can carry out: (a) More funding for anatomy to hire more teachers, buy more teaching resources (mainly digital tools), and improve teacher salaries, infrastructure, and research grants. (b) Improve the curriculum. Some components should be reviewed, modified, and trimmed according to need, keeping the learning objective in mind and returning to the general study cycle before medical school; and (c) Improve the selection of new teachers, which could be through certification and training of junior teachers, a more organized and oriented methodology for admission, and an award system by giving credit points to recent graduates to get their licenses; to be earned by teaching anatomy.

Teaching resources and activities

This would include acquiring digital tools, such as online material such as didactic videos, session recordings, anatomical software, and material for practical classes, including more cadaveric pieces or corpses and anatomical plastic models.

Teaching activities included involving students through interactive activities, such as online learning with gamification and LMS, clinical exposure in a hospital setting, and combining self-directed learning with the demonstration class during anatomy lab.

Anatomy staff

Participants formulated recommendations around three topics: (a) Responsibility to the students: as part of the commitment to being a teacher, it was deemed essential to communicate learning objectives, help students how to study anatomy, and focus on what students need; (b) Creating teaching content. Especially home-built videos based on the anatomists´ expertise; (c) Expressing the deficit. Participants commented on the importance of informing the corresponding authorities about the deficits and limitations that interfere with teaching.

Collaboration/alliance

Collaborating with foreign entities (universities, organizations) and other national institutions (hospitals or forensic medicine institutes) was mentioned as not requiring money but an investment of time and could facilitate the development of anatomy education and research. (Table 5)

Table 5: Theme: Solutions, Category: Suggested strategies.

Subtheme	Code	Quotes
Faculty management	More funding for anatomy	- *"… improve the infrastructure, both human resources and the fall buildings and availability of resources... include more faculty in my department, bring in resources to improve our classrooms and demonstration rooms to enable them digitally, and recruit a few more faculty members"* (Participant 5). - *"…this undergrad curriculum should be trimmed according to our objectives and needs...Also, some policies should be developed that require certification before coming to teaching, and junior teachers should do this..."* (Participant 8). - *"… before entering the faculty, carried out in the General Studies cycle. It was a learning cycle in general sciences. It was appropriate whether the student was getting used to university life..."* (Participant 7). - *"…we suggest that when you attend CME (continuing medical education) meetings, doctors take a percentage of those CMEs for doctors to be registered, so if they say you need 50 hours to be recorded. If they volunteer to teach, they are given those hours. So, instead of requiring 50 hours of those meetings, maybe you only need 40 plus 10, and then make our teaching hours more. So, if you get one point for one hour of meeting attendance, you can earn two points for one hour of teaching. So, make our teaching hours more attractive and give more points. So they don't have to pay for registration "* (Participant 4)
	Curriculum aspects	
	Selection of new teachers	
Teaching resources and activities	Teaching resources	- *"… we can engage the students by using these online materials, like the video of a dissection, step by step, and then explaining the procedures... You can use those kinds of digital tools… Regarding activities, gamification can create animated and interactive videos where the student is engaged."* (Participant 5). - *"… online teaching: We can have quizzes and gamification and teach many of these students a bit of material through any software. Another recommendation is sending students to hospitals; we can provide early clinical exposure, which can increase knowledge about clinical anatomy… You need to remove material from previous books and develop new books for system-based anatomy books"* (Participant 8). - *"In the case of practical classes, organize the activities on a rotating basis so that one group arrives at a practical activity, while the other group can be dedicated to studying with other strategies, such as practical class guides and solving clinical cases"* (Participant 1).
	Teaching activities	
Anatomy staff	Responsibility to students	- *"…instead of bearing it on the teachers, we make the plans clear and communicate it to the students… to keep the learning objectives simple" (*Participant 3) - *"The first thing is to raise (express) all the deficits that we have to the relevant institutions, starting from the directives of the University… Also, we anatomy teachers must teach study techniques to the students and teach them how to study anatomy. We would also have a share of responsibility for it."* (Participant 6) - *"We should develop a community of practice by involving anatomists who can create their content, and if you have one corpse, it is sufficient to develop a video. So then, with a locally available video camera, you can create home-built content that doesn't require much investment; only you need the expertise of an anatomist who knows dissection"* (Participant 5).
	Express the deficit	
	Create teaching content	
Collaboration	Foreigner entities	- *"Perhaps the local anatomy organization can link or associate with a sister organization... if the Association of Anatomists of other LLMICs will join, support, share problems and discuss... through promotion by an independent or international group…"* (Participant 4). - *"… strategic alliances could be made with hospital and security institutions. So if we had those alliances, the students could come by once a week to do their activity." (Participant 6).*
	National institutions	

Aspirational solutions but not realistic suggestions

Interviewees mused that solutions were not in the hands of anatomy teachers or institutions. They aspired to have a larger budget for education and health, improved infrastructure, fewer students, and more curricular time for embryology and neuroanatomy. (Table 6).

Table 6: Theme: Solutions, Category: Aspirational, but not realistic

Subtheme	Code	Quotes
Currently not solvable	Funding	- *"It isn't easy (about lack of funding). When you must fix things that are part of the economy or politics. You have very little say in how much money was allocated to the Ministry of Health and how much money was given to the Ministry of Education" (*Participant 4). - *"In the case of the corpses (lack of funding for maintenance), it does not depend on me. I know that it is the administrative part. That is merely leadership management*." (Participant 1). - *"Infrastructure, particularly in LLMICs like us, cannot be improved in one day, year, or even two years; it is a long-term agenda. But in short, I don't feel infrastructure can be improved…So, practically, things are difficult to solve because we can't reduce the number of students or increase the course duration"* (Participant 3).
	Teacher-student ratio	
	Infrastructure	
	Hours located to other Morphological sciences	

7.5 Discussion

There are few reports in the literature about studies on anatomical education in LLMIC. We conducted a brief review of the publications in Anatomical Sciences Education, a significant anatomy education journal, from 2020 to 2023, inclusive, and found that only 3.1% of the 354 articles were published by LLMIC authors; clearly, there is a gap in this literature.

Our study addressed the problems and solutions of anatomy teaching in LLMIC. We grouped findings into problems, solutions, and suggestions. The constraints were related to anatomy staff, environment and context, lack of funding, didactic resources' restriction, inappropriate infrastructure, and curriculum aspects. Solutions included low-cost didactic strategies, teaching when electric power was available, part-time anatomy teaching, student-organized extracurricular meetings, and learning resources privately subsidized by teachers and students. Proposals were linked to faculty management, teaching resources and activities, anatomy staff recruitment, and collaboration with other entities.

Problems

A shortage of qualified anatomy teachers has been reported in developed countries for over 60 years, attributed to the decline in anatomy PhDs. Furthermore, it extends to all medical education because it is increasingly challenging to obtain

experienced and qualified teachers to ensure high academic standards (20–24). At LLMIC, the faculty shortage is linked to severe economic problems, considering there is no hiring of new teachers despite often an increase in students. This leads to an unattractive teaching career with salaries insufficient to cover basic needs. This shortage has caused a rise in the teaching workload with more duplication of activities for multiple groups of students and the addition of other administrative tasks, which has led some teachers to demotivation and physical and mental fatigue. These factors can negatively influence the student's learning process by not adequately developing the academic activities. It is not easy to provide adequate follow-up and guarantee the attention and understanding of all students with very few teachers. Additionally, this overwhelming workload has given teachers less time to innovate and teach only the basics (pointing out anatomical structures) rather than seeking understanding and application of knowledge.

The lack of corpses was also a recurring theme. While in some cultures (such as Georgia), religion prohibits the use of corpses, or in some countries (such as Nicaragua or Mexico), the desecration of graves is prohibited by law; in others, we heard examples of students obtaining human bones of questionable origin to be used as a personal teaching resource, as one of the participants mentioned.

Furthermore, the need for more funds for research projects about anatomy and anatomical education could be closely related to a country's economic problems. It is expected that if the budget for projects is low, research aimed at the community's health needs will be prioritized (recognized priorities) (25) following the leading causes of morbidity and mortality in their country; that is, for hospitals and Public Health issues. Thus, anatomy teachers must face challenges every day through “palliative” adaptations, which, to a certain extent, have managed to stop the most significant deterioration in the quality of education. This solution, often at the cost of quality and private effort investment of a few motivated teachers, has a downside and is probably why the relevant authorities do not see the need to act on it.

It is not surprising that these unsatisfactory working conditions, together with sociopolitical and economic pressure, have somehow caused frustration and loss of energy in teachers, negatively impacting their motivation levels, which can be detrimental to the educational results institutions pursue because it can affect teaching performance (26) and, therefore, student learning. Furthermore, this adverse context has favored a brain drain migration of health professionals seeking better opportunities, coinciding with the emigration factors reported by Toyin-Thomas and Cols, such as remuneration, security, infrastructure, work environment, and job satisfaction (27), aggravating the shortage of teachers.

Solutions

Although these problems require a tactical and strategic level of action, the strategies implemented correspond to the operational level, with teachers showing commitment as an inherent responsibility to seek solutions related to student learning since, despite the limitations, not only economically but also politically, including freedom of expression mentioned by some participants, they still have a certain pedagogical didactic autonomy, evidenced by the various didactic strategies as the most mentioned implemented solution.

COVID-19 has propelled technology forward in various forms and fields, positioning ubiquitous learning as an excellent educational alternative: any place, any time, any technological medium, and diversity of academic resources (28–30), as a most economical educational method compared to others used in anatomy (31). This alternative included m-learning through social networks (WhatsApp and Telegram), which is employed to facilitate learning thanks to its free access, roles, and advantages (social, organizational, educational, and technical) (32). However, in LLMICs, the application of technology in learning (online, software, mobile) requires that institutions be prepared with trained human resources and a technological infrastructure (33), which includes a multimedia projector and adequate provision of services (electricity and internet), which are sometimes absent and, therefore, subsidized by teachers and students.

Despite the low salaries, teachers have used their own money for other teaching resources (sometimes in foreign currency), which is why teaching was also mentioned as a part-time job, since teachers usually have another, better-paying job to subsidize their teaching work, telling us that they teach for the love of art and intrinsic commitment.

Because anatomy studies the shape and structure of the human body, image-based learning is crucial, as it helps to develop a mental model of body structures and their spatial relationship and does not require significant financial investment. Furthermore, applying Mayer's multimedia principle of dual cognitive processing, presenting words with images instead of words alone strengthens the generative cognitive process (34) by integrating and organizing information to give it meaning and understanding. This is optimized when students actively participate through diagrams or drawings during lessons or self-study, improving understanding and memorization (35,36). However, some students do not have artistic skills and may take a long time or feel frustrated, so the teacher's guidance is essential when applying this strategy; that is, it should emphasize cognitive understanding and not the artistic realization of the drawing.

The practical use of anatomical knowledge in clinical applications and structure identification in imaging studies as a didactic approach does not require significant economic investment, has demonstrated effectiveness and acceptance by students (37,38), and motivates learning. Junior medical students begin their medical training with

optimism and are eager to receive any information that may be useful in their future medical practice; therefore, using applied anatomy and taking advantage of students' intrinsic motivation to be doctors makes it one of the most viable teaching strategies.

Anatomy teaching in LLMCs appears vulnerable due to severe economic conditions, weak management, and sociopolitical pressures. Those who kept teaching showed high levels of motivation to the point of personal sacrifices to make teaching happen creatively.

Limitations

Despite sending an invitation to medical schools in 82 LLMICs and an extended data collection period, we only obtained the participation of anatomy teachers from 11 countries, so we cannot generalize the results of our study.

Another limitation was the non-inclusion of students as critical agents in the teaching-learning process; it would be interesting to know the limitations and solutions from their perspective.

Nevertheless, our findings represent a start to continue this line of research and reveal the significant gap in knowledge of the Global South in the medical education literature, suggesting considerable room for continuous improvement.

Conclusions

Although anatomy teaching challenges that LLMICs face due to lack of funds require intervention at an intermedium or higher organizational level, some actions at the operational level can be implemented to mitigate them. Anatomical education in LLMIC is forced to adapt to the socio-economic context, not so much to trends in medical education worldwide. These adaptations are supported mainly by the teachers´ commitment.

7.6 Acknowledgments

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One participant requested anonymity.

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7.8 Annexes

Appendix 1 Questionnaire on Anatomy Education in Public Medical Schools in Low-Resourced Countries

Please confirm that you have read the information sheet about this study and that you agree to participate in this study (please state 'yes' in the white box)							
1. Your name				Country:			
2. Your email address							
3. Name your medical school							
4. How many first-year medical students enroll in each year?							
5. How many formal full-time equivalent teaching staff does your anatomy department have? (can you calculate the total in full-time equivalents if you have part-time teachers?)							
6. How many available anatomy teachers for actual teaching does your department have?							
7. How many medical student-teaching assistants does your department have?							
8. How many anatomy teachers have a medical degree?							
9. How many anatomy teachers do not have a medical degree?							
10. How many anatomy teachers have had formal postgraduate anatomy training?							
11. What must students pay for tuition fees at your medical school per year?							
12. What is the total annual budget of your anatomy department? (Leave open if unclear)							
13. Number of curricular contact hours for anatomy teaching	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Lecture hours							
Dissection lab hours							
Demonstration/ Practical class hours							
Other anatomy hours							
14. Please indicate the group size (nr. of students) for each type/year							
Lectures							
Dissection lab classes							
Demonstration/ Practical classes							
Other anatomy classes							

15. Are you satisfied or not satisfied with the anatomy knowledge of most of your students at the end of medical school? Please explain.	
16. Are you satisfied or not satisfied with the physical infrastructure for anatomy teaching (classrooms, facilities, lab space, ventilation, electricity, internet access, etc.) Please explain	
17. Tell us what you are most satisfied with concerning your medical school's anatomy teaching methods or conditions.	
18. If your department receives a large budget, what would be the first thing it should improve?	

19. What are the most challenging constraints to teaching anatomy at your institution, and how do you and your colleagues deal with them?	
20. What general advice are you for improving anatomy education in low-resourced countries (with little budget)?	
21. Please add any general comments about the above questions or anatomy education in low-resourced countries.	

Appendix 2 Multilanguage email texts to contact persons

Dear colleague,

We are approaching your public medical school to request participation in a survey study about the nature of your anatomy education.
Anatomy is central to medical education but is taught in very different ways. Affluent countries with abundant resources probably teach differently from low-resourced countries (LLMICs), but the medical education literature does not reveal how these countries manage to teach anatomy.
Our study attempts to identify how anatomy is taught in LLMICs, to publish a summary of ideas and guidelines for teaching anatomy with few resources, and to exchange that information among anatomy teachers.
We hope your school is interested in participating. Our request is:
Please send us the name and email address of an anatomy teacher in your school who is interested and able to answer the survey. We can adapt the study to any language incorporated in Google Translate. Please let us know what your preferred language is.

Best regards.

On behalf of the research team:

- Dra Ana Yoe-Cheng Chang Chan, MD., MSc., former teacher of Anatomy at UNAN-Léon University, Nicaragua
- Ronald Bleys, MD., PhD, Professor of Anatomy at University Medical Center Utrecht, the Netherlands
- Maarten van Leeuwen MD PhD, Radiologist (ret.) at University Medical Center Utrecht, the Netherlands
- Eugène Custers, PhD, independent Medical Education specialist, the Netherlands
- Olle ten Cate PhD, Professor of Medical Education, at University Medical Center Utrecht, the Netherlands

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Querido college,

Nos estamos acercando a su escuela de medicina pública con una solicitud para participar en un estudio de encuesta sobre la naturaleza de su educación en anatomía.
La anatomía es fundamental para la educación médica, pero se enseña de maneras muy diferentes. Los países ricos con abundantes recursos probablemente enseñan de manera diferente a los países de bajos recursos (LLMIC), pero la literatura sobre educación médica no revela cómo estos países logran enseñar anatomía.

Nuestro estudio intenta identificar cómo se enseña la anatomía en los LLMIC, publicar un resumen de ideas y pautas para enseñar anatomía con pocos recursos e intercambiar esa información entre los profesores de anatomía.
Esperamos que su Facultad de Medicina esté interesada en participar. Nuestra petición es:

Envíenos el nombre y la dirección de correo electrónico de un profesor de anatomía en su institución que esté interesado y pueda responder la encuesta. Podemos adaptar la encuesta a cualquier idioma que esté incorporado Google Translate. Háganos saber cuál será el idioma preferido.
Saludos cordiales.

En nombre del equipo de investigación:
• Dra Ana YoeCheng Chang Chan, MD., MSc., anterior profesora de Anatomía de la Universidad UNAN-Léon, Nicaragua
• Ronald Bleys, MD., PhD, Profesor de Anatomía en el Centro Médico Universitario de Utrecht, Países Bajos
• Maarten van Leeuwen MD PhD, Radiólogo (retirado) en el Centro Médico Universitario de Utrecht, Países Bajos
• Eugène Custers PhD, especialista independiente en educación médica, Países Bajos
• Olle ten Cate PhD, Profesor de educación médica, en el Centro Médico Universitario de Utrecht, Países Bajos

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Cher collègue,

Nous approchons votre faculté de médecine publique avec une demande de participation à une étude par sondage sur la nature de votre formation en anatomie.
L'anatomie est au cœur de l'enseignement médical, mais elle est enseignée de manière très différente. Les pays riches aux ressources abondantes enseignent probablement différemment des pays à faibles ressources (LLMIC), mais la littérature sur l'enseignement médical ne révèle pas' comment ces pays parviennent à enseigner l'anatomie.
Notre étude tente d'identifier comment l'anatomie est enseignée dans les LLMIC, de publier un résumé des idées et des lignes directrices pour enseigner l'anatomie avec peu de ressources et d'échanger ces informations entre les professeurs d'anatomie.
Nous espérons que votre école est intéressée à participer. Notre demande est:
Veuillez nous envoyer le nom et l'adresse e-mail d'un professeur d'anatomie de votre école qui est intéressé et capable de répondre à l'enquête. Nous pouvons adapter l'enquête à n'importe quelle langue qui intègre Google Translate. Veuillez nous faire savoir quelle sera la langue préférée.

Meilleures salutations

Au nom de l'équipe de recherche :
• Dra Ana YoeCheng Chang Chan, MD., MSc., ancien professeur d'anatomie à l'Université UNAN-Léon, Nicaragua
• Ronald Bleys, MD., PhD, professeur d'anatomie au centre médical universitaire d'Utrecht, Pays-Bas
• Maarten van Leeuwen MD PhD, radiologue (retraité) au University Medical Center Utrecht, Pays-Bas
• Eugène Custers PhD, spécialiste indépendant en éducation médicale, Pays-Bas
• Olle ten Cate PhD, professeur de formation médicale, au University Medical Center Utrecht, Pays-Bas

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،العزيز زميلي

.بك الخاص التشريح علم تعليم طبيعة حول استقصائية دراسة في المشاركة لطلب العامة الطبية كليتك من نقترب نحن
بشكل بالتدريس الوفيرة الموارد ذات الغنية البلدان تقوم أن المحتمل من .جدًا مختلفة بطرق تدريسه يتم ولكن ، الطبي التعليم في أساسي التشريح علم
.التشريح علم تدريس من البلدان هذه تمكنت كيف تكشف لا الطبي التعليم أدبيات لكن ، (LLMICs) الموارد منخفضة البلدان عن مختلف
وتبادل قليلة بموارد التشريح علم لتدريس التوجيهية والمبادئ للأفكار ملخص ونشر ، LLMICs في التشريح علم تدريس كيفية تحديد دراستنا تحاول
.التشريح معلمي بين المعلومات هذه

:هو طلبنا .بالمشاركة مهتمة مدرستك تكون أن نأمل

أي مع الاستبيان تكييف يمكننا .الاستبيان على الإجابة على والقادر المهتم مدرستك في التشريح لمعلم الإلكتروني البريد وعنوان الاسم إرسال يرجى
.المفضلة اللغة ستكون ما نعرف دعنا فضلك من .Google Translate في دمجها تم لغة

التحيات أطيب مع

:البحث فريق عن نيابة
• Dra Ana YoeCheng Chang Chan ، جامعة في التشريح مدرس UNAN-Léon ، نيكاراغوا
• هولندا ، أوترخت الجامعي الطبي المركز في التشريح أستاذ ، دكتوراه بليس رونالد
• هولندا ، أوتريخت الجامعي الطبي المركز في (متقاعد) أشعة أخصائي ، الطب في دكتوراه ، ليوين فان مارتن
• هولندا ، مستقل طبي تعليم أخصائي ، الدكتوراه درجة على حاصل كاسترز يوجين
• هولندا ، أوترخت الجامعي الطبي المركز في الطبي التعليم أستاذ ، Olle Ten Cate PhD

亲爱的同事,

我们正在与您的公立医学院接洽，请求参与一项关于您的解剖学教育性质的调查研究。

解剖学是医学教育的核心，但以非常不同的方式教授。资源丰富的富裕国家的教学可能与资源匮乏的国家 (LLMIC) 不同，但医学教育文献并未揭示这些国家如何设法教授解剖学。

我们的研究试图确定如何在 LLMIC 中教授解剖学，发布关于以很少的资源教授解剖学的想法和指南的摘要，并在解剖学教师之间交换这些信息。

我们希望贵校有兴趣参与。我们的要求是：

请将您学校有兴趣并能够回答调查的解剖老师的姓名和电子邮件地址发送给我们。我们可以将调查调整为包含谷歌翻译的任何语言。请让我们知道首选语言是什么。

此致

代表研究团队：

• Dra Ana YoeCheng Chang Chan， 医学博士、理学硕士、尼加拉瓜 UNAN-Léon 大学解剖学教师
• Ronald Bleys, 医学博士 博士，荷兰乌得勒支大学医学中心解剖学教授
• Maarten van Leeuwen 医学博士，荷兰乌得勒支大学医学中心放射科医师（退休）
• Eugène Custers 博士，荷兰独立医学教育专家
• Olle ten Cate 博士，荷兰乌得勒支大学医学中心医学教育教授

CHAPTER 8

GENERAL DISCUSSION

This thesis presents a series of studies that not only delve into the nature of anatomy teaching in a changing world but also underscore their crucial role in shaping the future of medical education.

8.1 Background

As explained in Chapter 1, gross human anatomy is one of the oldest branches of medical knowledge. Therefore, from a historical point of view, human anatomy can be considered one of the fundamental pillars of medical training (1). Human anatomy as a science developed significantly from ancient Greece to the 19th century, taking a central role in the evolution of medical sciences. The 20th century was the beginning of the metamorphosis of anatomical sciences. Throughout this century, several changes occurred, both in anatomy as a science and in teaching anatomy. Whereas anatomy as a science of discovery has a history based on the dead body, medical imaging methods now facilitate the direct visualization of pathological conditions around anatomical structures and allow the exploration of living anatomy (2,3). In the educational field, implementing teaching strategies such as e-learning and mobile learning and using social networks such as YouTube, Facebook, and WhatsApp (4–7) has allowed students to learn continuously and adaptively, promoting autonomy, personalization, and the development of digital skills (8).

The evolution of anatomy has been one of the pillars of the advancement of medical sciences because it established medicine's scientific and linguistic foundations. It also oriented the culture of medicine towards a reference to health and normality. Furthermore, it promoted observation and experimentation as an approach to scientific study, thus displacing the educational approach based on pre-established texts and ideas.

The requirements of health professional workers to cover health needs have led public medical schools in low-middle-resource countries to the challenge of providing quality medical training to an increasing number of students but with the same number of, or even fewer, qualified teachers, the same amount of teaching resources, and limited access to equipment and infrastructure for education (9–16).

The growth of science and education health and new challenges in anatomy, such as difficulty in obtaining and maintaining cadavers, the reduction in the number of teaching hours, and the educational trend of promoting applicable knowledge and value in professional practice, led us to investigate the global perspectives on optimizing its teaching, addressing differences between high-income and low-middle-income countries, and exploring how resource-scarce countries fulfill their obligation to teach anatomy.

8.2 Anatomy Education Development Prospects

If we ask experienced medical education teachers and academics what stands out in the direction of anatomy teaching (chapter 2). They report that the position of anatomy education in medical schools has declined, likely due to a limited proportion of curricula, declining research, and fewer qualified teachers. In their view, Curriculum developers should consider horizontal and vertical integration and focus on problem-solving and clinical anatomy. Proposed directions include early anatomical knowledge foundations, integrating anatomy with radiology, focusing on specialty-oriented graduate education, peer teaching, and incorporating technological advances to optimize student and teacher experiences.

Implementing additional online anatomy education was suggested to be helpful and facilitate the study of anatomy. In addition, the integration of radiology and anatomy was regarded to positively impact the perception and performance of medical students in both the preclinical and clinical years. The recommendation is to draw more on structured; self-directed learning approaches complementary to direct teaching of the medical curriculum, especially as an alternative for teaching anatomy in countries where dissection is challenging to organize. We found that students from higher-income countries appreciate anatomy education more than those from low and lower-middle-income countries (LLMIC). This perception of difference seems partly caused by culture and linked to affluence. Although they all agree that anatomy education is important, becoming an anatomy teacher or scholar is usually not regarded as an exciting career option for themselves.

8.3 Methods of Anatomy Teaching

Based on the literature review (chapter 6), we identified 14 methods of teaching anatomy. According to their conceptual feasibility (related to complement academic learning, which includes its coherence with the educational approach, the skills, and the content to be taught), dissection and technology-enhance learning approaches appeared to have more benefits than other approaches. Dissection has, besides benefits, many specific drawbacks. Lectures and peer teaching showed better technical and economic feasibility. Educational platforms, radiological imaging, and lectures showed the highest operational feasibility (which includes the organization, infrastructure, and the time required). Dissection and surgery were found to be less feasible in terms of operational, technical, and economic characteristics. However, anatomical education in LLMIC is forced to adapt to the socio-economic context and not so much to trends in medical education worldwide. These adaptations are supported mainly by the teachers ‘commitment.

8.4 The future of anatomy as a leading scientific discipline

During conversations with experienced medical education faculty on the ways forward for teaching anatomy (chapter 2), one of the interviewees said: "*The classical form of anatomy will disappear if we do not have enough budget; any other specialist (radiologist, surgeon) can teach anatomy*." It may be a bit strongly expressed, but it can be argued that it is still fundamentally correct. It may be difficult for an anatomist to accept, but anatomy education must evolve and adapt to the current context. Anatomy has been a protagonist for centuries and has contributed to medical sciences. Anatomy education remains crucial because it is the basis of medical training. But now, the tip of the spear is in other new medical sciences, and anatomy has become part of the handle of that spear. Therefore, anatomy teachers must first accept that the anatomy teacher is no longer the movie star but is still vital; it is instead one of the first supporting actors/actresses. If we finally understand this, the reduced hours allocated to pure anatomy education in the medical curriculum should not be a problem. In addition, this could facilitate the implementation of real integration, both horizontal and vertical.

Several journal publications on anatomical education mention the reduction of hours and highlight the importance of anatomy. So far, no article has argued that anatomy is unimportant. Yet, anatomy education researchers do insist on saying this as if anatomy has lost its leadership position. Of course, all anatomy educators try to find the best way to teach anatomy, given the circumstances. If anatomy teachers and education scholars accept new anatomy roles within medical sciences, true integration (vertical and horizontal) could be acceptable, better, and authentic. Sometimes, when faculty members talk about integration, they think they implement it by putting the different disciplines in one block of the medical program. However, teachers teach their discipline separately, which does not constitute real integration; it is only “chunks" of information. Real integration implies interdisciplinary solid teamwork.

8.5 Online Anatomy Education

Our study on the effectiveness of an online course (chapter 3) showed, as a somewhat unexpected result, good attendance and acceptance of the OSPE (objective structured practical exam) in anatomy, both by the experimental and control groups. Despite not being the study's objective, the authors saw the excellent response of the participants in each OSPE, and they held a focus group to discuss the participants' perceptions of the OSPE. At that time, the OSPE was a new way of evaluating that the participants perceived as more objective than the regular assessment used in anatomy since it did not depend on the judgment of the professors or the student assistants but on students' performance. In addition, it helped students detect weak points that needed to be reinforced. The above and the fact that there were no differences between both

groups (experimental and control) in the regular anatomy evaluation made us consider anatomy assessment in resource-deprived countries as a future object of review and study. Another unexpected result of this study was the gradual decrease in the experimental group's participation in the online course activities due to its non-mandatory nature and the absence of summative recognition in their official grades. This could indicate that the extrinsic motivation of grades is an essential factor and of greater weight than learning itself, which students consider in their training.

8.6 Radiological anatomy

In our research on the use of radiological anatomy (chapter 4), the most relevant salient results were: 1) the perception of the usefulness of the ultrasound was the lowest, 2) the study guide as a teaching resource obtained the highest perception of usefulness, and 3) there was no difference in performance between junior and senior students. The use of ultrasound in teaching anatomy has been described in medical literature as helpful and economically accessible (17–23) for the participants. However, participants in our study regarded it as the least proper radiological technique, difficult to understand, and impractical for learning anatomy. Nevertheless, we consider it crucial to train students' minds to become accustomed to ultrasound-generated images from the early stages of their training since it is one of the most rapidly upcoming radiological techniques advocated for anatomy teaching due to its biosafety, accessibility, and cost-effectiveness (24).

Regarding preferences in teaching resources, the study guides, although mainly textual resources, appeared to surpass the atlas in attractiveness. Atlases are visual in nature and, therefore, more in line with the essence of anatomy. This may indicate that students prefer structured, condensed resources that guide their learning, thus highlighting the importance of the self-directed learning approach and the teacher's role as facilitator. Due to the clinical exposure of the senior students, one would expect them to be more familiar with the diagnostic means than the junior students. Therefore, their performance in the radiological anatomy course implemented would be better. However, we observed that the performance of both juniors and seniors was similar with very little difference. This result can be understood as, for both groups, the content addressed in the course was new, mainly because in teaching hospitals in countries with few resources, the availability of radiological techniques is limited so that senior students could have more experience in clinical aspects, but not in recognition of anatomical structures in tomography, MRI and ultrasound.

8.7 Challenges in low-resourced countries

When we compared the interests and preferences about anatomical education in students from a high-resource country with those from a low-resource country (chapter 5), surprisingly, we found that all study participants consider the amount of anatomy in the medical curriculum sufficient. This is contrary to reports in the literature, which highlight the reduction in the number of hours located in the medical curriculum and the dissatisfaction of clinicians and teachers about insufficient anatomical knowledge on the part of students (17,25–27). Curiously, teachers who provide education consider it insufficient, while students who receive the education believe it is enough. This could be because most such articles reported in the literature have been written by professors and researchers who feel that what they teach is minor compared to what they, as students, received or as teachers know about the discipline.

The study on the strategies and challenges of anatomical education in low- and middle-income countries (chapter 7) yielded more unexpected results than most of our other studies. To begin with, we found it challenging to secure a reasonable response from, or even to get in touch with, the 82 public medical schools from an established list (a directory of the World Federation of Medical Education) to which the invitation was sent (receiving a reply in <5%) and explored other ways to organize a reasonable response. This tells us that research in medical education, specifically anatomical education, is not felt a priority or is not so common in those countries; as they expressed, the priority in research is mainly in public health issues.

A result that quite surprised us was the challenges mentioned by some teachers, such as vandalism, insecurity, and limited freedom of expression, topics that are usually difficult to find in medical literature. However, thanks to the confidentiality guarantee in the study, some teachers felt free to mention them. These sociopolitical problems are characteristic in countries with poverty and social marginalization, where freedom of expression is strongly related to fundamental socioeconomic rights (28). It should be noted that all the countries interviewed, according to the 2023 Amnesty International report, are classified as being in “difficult situations” or “very serious situations” concerning freedom of expression (https://www.es.amnesty.org/en-que-estamos/blog/historia/articulo/libertad-de-prensa-principales-amenazas/) (29), including countries currently having a regimen that can be qualified as totalitarian in which academic leadership appointments are political rather than based on academic expertise. Therefore, the political context of these countries is another critical problem since it can manifest as instability, socioeconomic conflicts, and chronic armed conflict, all affecting the quality of academic education.

As a challenge, we expected to hear about difficulties in obtaining and maintaining teaching resources. Still, we did not expect that one of the strategies used to solve this problem would be self-financing, where teachers and students would use

their private money to guarantee the availability of some teaching resources. Likewise, we did not expect some students to resort to grave desecration to obtain bone specimens of skulls to complement their anatomy study, despite this being punishable by law in some countries. These extreme measures indicate the degree of commitment and interest teachers and students have in ensuring learning activities are carried out.

8.8 A critical reflection on methods used

Various methodologies were implemented to answer the research questions. We discuss these, highlighting their strengths and shortcomings and suggesting future follow-up studies.

For the study described in Chapter 2, we used a qualitative approach and thematic analysis to produce a perspective article. It employed in-depth interviews to organize and analyze the information obtained from conversations with medical educators from different domains. The information obtained from the interviews was combined with our vision as a research team fueled by the available literature.

While we believe that the perspective on the future of anatomy education is determined by the people involved in it, we consider it necessary to have a diversity of opinions if we are to have an informed perspective and overcome one-sided thinking as anatomists and thus avoid being biased by our views and own preconceived ideas. The different opinions helped us think critically about our beliefs and ideas, and by listening to the opinions of a wide range of people, we better understood the topic. We would probably have had a one-sided discussion if we had only talked to anatomists. Considering what other medical educators thought about the future of anatomy allowed us to understand the environment better. The contributions of others constituted valuable information, which helped us to gain a critical and objective perspective.

Nevertheless, this chapter does not reflect a consensus methodology in the true sense; for instance, we would have used a Delphi technique. Our panel of experts is concerned with a convenience sample, and some may question how we defined expertise. The Delphi methodology (initially designed for predictive projections to help institutions and companies develop policies) would be a more balanced method. The Delphi procedure would include (a) a more thoughtful selection of well-defined experts in a larger panel, (b) a carefully designed survey, (c) a two or three-step investigation of independent opinions with feedback to the panel members between the steps, (d) a consensus conclusion, based on predefined consensus levels (30,31). We can consider our approach in Chapter 2 a preliminary study, upon which a Delphi study could follow.

In Chapter 3, an explanatory mixed methods procedure was implemented to explore the effectiveness of an online anatomy course in a low-resource country.

Although the explanatory method involves more time than the other mixed methods, the quantitative data obtained first gave us a general image of the topic, allowing us to identify the key points to develop in-depth in subsequent focus groups (32–34).

For the quantitative part, a true experiment (post-test two-group experimental design) was applied, which allowed us to test the effect of the online course (experiment) as an independent variable on performance in the evaluation (dependent variable). Threats to internal validity were reduced due to the random assignment and the presence of both groups (experimental and control). Because the other educational approach to optimize anatomy was studied separately (Chapter 4), the next step would be to implement a factorial design to investigate the effect of both the online course and the integration with radiology on the teaching of anatomy, always focused on its implementation in low-resource countries with the traditional teaching of anatomy. In a future study, this could allow us to explore the interactions between the independent variables and obtain inputs to optimize the implementation of these strategies in low-resource contexts (32,33). For example, the effectiveness of radiological anatomy in teaching anatomy in the virtual versus the face-to-face modality could be measured and compared. Similarly, radiological images could be measured and compared during online lectures versus face-to-face practical classes.

For the qualitative part, focus groups were used, which allowed us to investigate and explain a phenomenon. This online anatomy course, at that time, was the first online anatomy course in the low-resource country where it was implemented (Nicaragua). Also, it was the first time that the OSPE was used in that study group. In addition, there was not much information available in the literature, allowing us to build theories about said phenomenon (32,33,35). Because both virtuality and OSPE were subsequently adopted regularly in the teaching of anatomy in that low-resource country that was the object of the study, the next step would be to carry out a participatory action research in which there is no need to wait to translate knowledge, and actions into practice after producing knowledge. Furthermore, this will allow us to enhance online learning and OSPE and investigate the implementation of these innovative practices and their impact on students and anatomy staff (33,36).

In Chapter 4, using a quantitative approach, specifically a cross-sectional group comparison survey design (senior versus junior), we tested the effectiveness of radiological anatomy on anatomy learning. Employing standardized questionnaires, we obtained information from subgroups of medical students with different degrees of experience and knowledge (senior and junior). Thus, we described and compared their preferences and opinions on the topic under study. As mentioned above, it would be advisable to carry out a factorial design study to investigate the joint effect of the online course and the integration with radiology in the teaching of anatomy in low-resource

countries and to assess whether there is a connection between the factors (interaction or secondary effects) (32,33).

The study described in Chapter 5, also with a quantitative cross-sectional group comparison survey design, was conducted to understand and determine the cultural and economic differences and similarities between countries with high (Netherlands) versus low (Nicaragua) resources and students' preferences about teaching anatomy. This design allowed us to study several variables at the same time (importance of anatomy, quantity, and quality of anatomy in the curriculum, the anatomy major, and educational approaches to anatomy) and compare between subgroups (Dutch and Nicaraguan students). Another advantage was the remote data collection, as the subgroups were geographically distant (Europe and Latin America). The above allowed us to know the population under study regarding their preferences and opinions, considering cultural and economic differences. However, one of the disadvantages was the low response rate, which occurred with one of the subgroups (32,33,37).

Given that the information available in the literature on comparing opinions on anatomy education in students from high- and low-resource countries is scarce, a subsequent study to delve deeper into the differences found would be a mixed explanatory approach, in which the quantitative approach would be the same design, that is, the cross-sectional group comparison survey design. However, the sample should be enlarged to include students from other countries. This would be followed by a qualitative phenomenological study that will allow us to understand and describe the participants' preferences from their perspective, contextualizing their experience and searching for possible meanings of the selected options (32,36).

In Chapter 6, we used the scoping review technique to identify and map the available evidence on approaches to teaching anatomy in countries with severe resource shortages. This provides an overview of the topic and determines the volume of literature and studies available. It also allowed us to examine emerging evidence on the relatively new subject and analyze knowledge gaps (38,39).

Ideally, a follow-up review article would be a systematic review of the challenges and strategies of medical education in LLMICs to identify, evaluate, and summarize the findings and implications of all relevant individual studies of the challenges and strategies implemented in teaching anatomy. That is, highlighting and recovering relevant international evidence to inform the practices and policies of these countries about medical education. This would give us the closest approximation to the truth of the available evidence. However, there will always be publication bias since the published articles do not reflect the real implemented research and teaching practices (black literature and even white papers will always forego experiences that never get published) (38,39).

For the study presented in Chapter 7, an explanatory mixed method was used to explore the challenges and strategies that public medical schools implement in low-resource countries. For the quantitative part, we used a self-administered mail survey design using a standardized questionnaire to collect data and describe teachers' opinions and circumstances about their teaching practices and challenges in providing quality anatomical education. Self-administered surveys via email allowed us to collect information remotely from participants across four continents (Asia, Africa, Latin America, and Europe). Of course, this data collection technique fell victim to non-response bias, as information could only be obtained from 13 participants despite having sent invitations to 82 countries (32–34,37).

We conducted in-depth interviews for the qualitative part. With the thematic analysis, we tried to generalize the information obtained by the participants and its constant comparative analysis since, until now, there was no pre-existing theory on the topic under study. Hence, the concepts and assumptions were formulated throughout the research in an inductive analysis. The use of in-depth interviews allowed us to try to understand anatomy education in LLMIC from the teacher's point of view as one of the protagonists of the teaching-learning process, analyzing their experiences and relating them to their day-to-day teaching practices (32–34,36).

In this last study (chapter 7), we identified and categorized the main challenges and strategies teachers implement to face these challenges. It would be interesting to explore whether our results can be extrapolated to other low-income countries since the low participation rate does not allow us to generalize them. Therefore, we believe that to continue, a survey study should be carried out using a standardized questionnaire built based on our results to apply it to a more significant number of participants that includes more low-income countries and thus be able to have an estimate closer of reality about anatomy education in low-resource environments.

8.9 Anatomy education: trends and feasibilities

Medical education has always been present in the motivations and actions of medical communities. Its evolution has been related to the interests and concerns of those who have taught medicine and subordinated to the dominant economic and social structures in the societies where it has been carried out. Anatomy is the oldest medical discipline, beginning in Classical Greece (6th century BC); the medical doctrine taught to students was centered around a teacher of recognized prestige and was characterized by discipled learning, “See how I do it so that you can do it later” prevailed until the Middle Ages (40). Thus, we see that for centuries, anatomy education was marked by a behaviorist educational approach centered on the teacher and supported mainly by anatomy textbooks and atlases. In the middle of the last century, teaching

strategies and resources have changed with adopting the constructivist educational approach and the growing use of technology in all areas.

With the COVID-19 pandemic, the medical education literature became loaded with articles demonstrating and supporting using different forms of technology to optimize students' learning capacity. These articles present technology as a helpful tool for medical education since it increases the practical skills and safety of the student by providing an experience like clinical practice but with less risk (41).

Moreover, the adaptability and efficiency of the Internet as a resource platform have transformed students' approach to self-directed learning, considering their needs and motivations. Students' habits and preferences have also evolved since they do not depend on books to acquire knowledge (42) but have incorporated different technological resources into their learning routines to complement traditional classroom methods. Thus, learning anatomy is more effective when multiple pedagogical resources are integrated; the aim is to optimize, not replace (42,43).

However, the choice of teaching resources will depend not only on the student´s preferences but also on their experience, the quality and availability of the resources, the tutor's recommendations, the study program, and the educational approach (44).

Sometimes, it can be frustrating to observe that after hours of teacher preparation, very few students attend lectures and that, instead, they prefer to review the information found on the web. This is nothing more than a reflection of the evolution that education, in general, has had, that is, the student as the architect of his knowledge and center of his teaching process, who searches for didactic resources on his own. This is not new, but anatomical education, which has been strongly traditional, brings about a paradigm shift in the role of anatomy teachers. Because the use of learning resources from the Internet can result in a source of information that is inaccurate, incomplete, and without a scientific basis (42), a new role of anatomy teachers is that of facilitator and counselor who, based on their experience and mastery of the subject, can examine, and select the information and then recommend it to the students (44). This does not mean that the “icon” of the teachers is relegated; on the contrary, they play a fundamentally active role in the direction of the student's learning; they work like a compass because they guide the student on which path to take, helping him, also to clarify doubts; indispensable functions, taking into account the risk of false or inaccurate information that students may find on the web. The above leads us to believe that the objective of the lectures should not only be to transmit or instruct on new topics, but rather it should be a space in which students can discuss and express their doubts about a topic, as well as analyze the application of the new knowledge, thus also promoting clinical reasoning with a better morphological basis. This means the student can blend anatomical knowledge, experience, and critical thinking to construct new knowledge and its subsequent use in clinical scenarios. That is why hiring experienced, research-oriented, and pedagogically qualified teachers who know how to implement

technological innovations in the teaching of anatomy is a factor in its success (25) and, at the same time, a current challenge for medical schools, both in high-income countries, where the number of students interested in anatomy teaching has decreased, as in countries with limited resources, where they cannot afford a sufficient number of teachers.

However, the teaching resources on the web and the different anatomy software are diverse and can be expensive, even for students from developed countries. In countries with limited resources, this is compounded by the need for a reliable internet connection (42). Therefore, inequality of access to online technology and faculty's untrained mastery of technological innovations are necessary factors that tell us that not all trends are viable for all contexts or realities.

As we found in our study described in Chapter 7, a viable alternative is messaging applications such as WhatsApp and Telegram, whose use in education was enhanced by the recent pandemic, thus confirming its multiple advantages, especially useful in scenarios with restricted resources. Some benefits are free portability, low data requirements, facilitating the distribution of digital resources in various formats (audio, videos, texts, URLs), and their review even offline (5,45,46). Furthermore, messaging applications´ benefits are not limited to accessing or sharing teaching resources but extend to complement student-student interaction (allowing collaborative learning) and student-teacher interaction (facilitating the discussion of topics and clarifying doubts).

One of the proposed paths forward that can contribute to meeting the demands of increasing enrollment and reducing the ratio of professors to students in higher education is peer teaching, which is widely reported in the medical literature and has good results (47,48). As the tutors were closer to the students than regular teachers, helping each other and learning by teaching, there was cognitive and social congruence, which is vital to the success of this strategy (49). The benefits seem more significant for the student tutor who develops personal, educational, and professional skills (50–52). For the student, the tutor can be an inspiring factor, seeing someone one or two years older in the role of teacher, and a calming factor, which helps reduce anxiety, as the tutor is a student from the same social circle; therefore, a figure not of authoritative but trusted and close. In addition, it is much cheaper than hiring new teachers because some student tutors are even volunteers.

With the decline of research in the anatomical sciences in the second half of the last century, the advent of new biomedical knowledge, and the difficulty in obtaining and maintaining human cadavers, the decline of the proportion of teaching of anatomy in medical curricula is a reality that will probably not return to its glorious status as in the Renaissance, even though the fundamental role of anatomy in the training of the future doctor and in supporting modern medical practices is known to all.

Currently, modern medical curricula advocate horizontal, vertical, or spiral integration, where what is sought is the application of knowledge in a clinical context

and the early ability to practice essential skills such as critical thinking and solving clinical problems (53). For medical students to minimize medical errors, anatomy taught with theoretical and practical applications should be supported with a clinical approach; this will contribute to developing students' medical skills (54,55).

Integrating radiology with anatomy education through real-world clinical scenarios and images has become a popular educational approach. This approach offers early and meaningful clinical experiences and bridges the gap between anatomy and clinical medicine (21, 22). Radiology is closely related to other clinical sciences since it supports diagnosis and monitoring in all medical specialties.

In the medical literature, numerous studies report the usefulness of radiology in the teaching of normal anatomy, which lies in significant learning by serving as a triggering element of the curiosity and motivation of the student, who is eager for clinical information due to the desire to be a doctor However, it is not a one-way relationship in which only anatomy benefits from radiology. As an image-based science, radiology requires anatomy as the base knowledge and foundation of the radiologist's work. By mastering anatomy, diagnosing pathologies is simple; knowing what is normal makes it easier to detect the pathological.

Despite its usefulness, there are certain aspects of feasibility when implementing integration in the teaching of anatomy, as mentioned by Kalil et al., who summarize them in four categories that apply to realities in countries of the southern globe: (1) program design, (2) teacher training, (3) resource availability, and (4) educational contexts (55).

Regarding the program design, the challenge we consider most difficult to manage is that basic and clinical teachers agree on the content of their respective subjects since each one clearly promotes more content from their own discipline.

Concerning teacher training, in addition to pedagogical training, there are particularities of other subjects that teachers must at least know if proper integration is to be used; that is, the teacher who is responsible for teaching a topic must not only teach what corresponds to their discipline on the subject but should also teach the content of the other disciplines in an integrated, balanced and unified way. Otherwise, they would be "chunks" of information one after another. The idea of integration is that it is "interdisciplinary" and not just "multidisciplinary."

The challenge regarding resource availability may be even more significant in low-resource countries, many of which have only X-ray facilities in their hospitals, and access to images from other radiological techniques is limited to private clinics or exceptional cases. On the other hand, although one can acquire radiological photos online, these may need to be of better quality, their use may be limited by copyright, or they may require help finding the image most representative of the topic to be taught.

Other especially significant challenges in low-resource countries are educational contexts regarding physical facilities. For an adequate radiological anatomy session,

well-equipped laboratories with computers and screens and the appropriate software to read the radiological DICOM image file (Digital Imaging and Communications in Medicine) type are required. These facilities require air conditioning, adequate furniture, and constant equipment maintenance for correct operation. This represents an economic investment and maintenance costs that many medical schools in low-resource countries cannot afford.

8.10 Health professions education in Higher and Lower income resources environments

The objective of medical education, regardless of geographic location, is “better training for better doctors.” Doctors must respond to the health needs of the population they serve. Medical education, therefore, is guided by medical practice and influenced by the sociocultural context. Times are changing, and medical schools must respond to a transforming healthcare system and rapid expansion of new medical knowledge; therefore, doctors' training must adapt to changes in medical practice. Today's physicians must be able to integrate rapidly expanding information, manage a changing healthcare system, understand the determinants of health and disease, work effectively in teams, and maintain personal and professional development. The pace of change in medicine makes learning a necessary lifelong process.

Knowledge about medical education is generated worldwide; however, the medical education literature comes primarily from countries known as the “Global North,” leaving knowledge of the Global South lost or unknown. This dominance of the Global North in medical education generates a cultural dominance that produces the effect of "othering" in patients, students, and professionals from the Global South (56,57).

The practice and terms of Global South and Global North have their origins in racism and colonialism, which have created a false superiority sense between nations (58). The term "global north" designates industrialized (also called "developed") geopolitical contexts that include countries that were colonial powers and are mainly located in the northern hemisphere of the planet; countries such as the US, those in Europe, and Australia are in this group. The term “Global South” refers to resource-poor or newly industrialized nations (called “developing”) that were not colonial powers and are conceptualized as poverty-stricken and underdeveloped. This group constitutes 85% of the world's population and includes the countries of Africa, Asia, and Latin America (56,57,59).

The dominance of the global north in international medical education research, scholarship, and teaching has implications for the content of curricula and related competencies of health professionals. The best evidence from the global North may not

be valid in the global South, as some recommendations may be unfeasible to implement and others contextually inappropriate and ineffective (59).

That is why all countries must be able to conduct research relevant to their health and education needs. However, we find very few articles published by authors from low-income countries in scientific journals. Kusurkar refers to 94% of articles published by authors from countries in the northern world (57), so only 6% of the articles were written by researchers from the southern globe. This percentage coincides with the 3% of LMIC authors we found in our search in the ASE journal.

Several factors may contribute to this low percentage, such as (1) the power structure of knowledge that is biased and dominated by journal editors from the northern globe, so research from the global South is “othered,” and researchers are seen as non-experts, their localized knowledge and findings inconsequential, invalid and irrelevant to international audiences, and therefore excluded; (2) lack of resources or access to Western literature and scientific writing training (57); (3) language barriers, as not all teachers are fluent in academic English; (4) due to funding limitations, many medical schools do not allocate budget for research in medical education, as there are competing health priorities and limited budgets for education; and (5) many medical schools in low-income countries suffer from a brain drain of academic staff to developed countries: higher incomes, faculty attrition, and low staff morale.

Concerning this last factor, brain drain, it is essential to mention that the minds of people born and raised in colonized contexts remain colonized. The descendants of colonized peoples aspire to the ideals and ideas of the colonizers. This phenomenon, known as “mimicry” or “sly civility(56),” is a means of survival in a context exacerbated by insufficient training and continuing education opportunities to improve teachers' skills.

Given the racist and discriminatory connotations behind the terms Global South and Global North, perhaps it would be most appropriate not to use those terms. Instead, we could use income as a source of distinction, mainly when it provides some insights into economic variables. Social factors define a country's needs and highlight the nuances within countries. In any case, as Khan et al. state, we should use terms that recognize the differences between countries and people and respect how they want to be described (58).

8.11 Next steps

Traditional and innovative teaching modalities have been studied for their effectiveness in isolation. Although it is common for educational studies to focus on a combination of teaching methods and products, the challenge now is to weave these multimodal approaches with cost-benefit analyses to provide insights into their programmatic products in the context of their resources. Cost and value research should be conducted in parallel with studies that evaluate educational effects and the

experience of protagonists (students and teachers), whether quantitative or qualitative, to improve our understanding of the resulting information for decision-making. These investigations should consider not only the tools of anatomy education (e.g., human body donors, digital resources, teaching resources, etc.) but also curricular aspects, such as pedagogical approach, learning program design, and implementation.

In our research, we have explored the opinions and preferences of different stakeholders, such as students, anatomy teachers, and medical education experts. We consider that one of the next steps to follow would be to explore the decision-makers opinions since most of the alternatives to implement will depend on what they believe is essential, thus influencing various aspects of medical education. , such as supporting students with a wide range of learning needs, supporting teachers in developing educational research, providing options to meet individual student preferences, developing desired non-traditional programs, implementing educational innovations, etc.

Part of our results reflects students' preferences for the type of anatomical education. Likewise, we investigate the challenges and strategies of anatomical education from the teacher's perspective. The next logical step would be to explore these challenges and techniques from the student's perspective in difficult circumstances, providing us with input to understand better and see the whole picture.

The low percentage of educational journal publications by LMIC authors affects not only anatomy education but also medical education in general, so it would be pertinent to explore the protagonists' challenges, strategies, and preferences related to other basic medical sciences. This would give inputs that help construct a comprehensive and analytical information framework regarding the state of medical education in low-resourced settings, shaping the premise for transformative "north-south" exchange that advances learning from each other.

Based on our results and their corresponding analysis, we can conclude that anatomy is still current and essential in medical sciences. However, it is no longer in the traditional leading role it has played for centuries. In addition to the change in the leadership position, the change also occurs in the focus of their practice, not so much as science, but more with an educational approach, and as such, their way of teaching is in correspondence with current educational paradigms, where the student is the architect of his own knowledge, moving the teacher in the role of a facilitator of that learning. Therefore, both the strategies and the teaching resources must promote self-directed learning. Given its visual and practical nature, anatomy can be integrated horizontally (with other basic medical sciences) and vertically (with clinical sciences, especially radiology). In educational settings with limited resources, the commitment and motivation of teachers and students are vital to the development of anatomy and all medical sciences. In anatomy, some of the most viable strategies for facing the main challenges are visual learning, applied anatomy, and using available technology, such as WhatsApp or another creative, low-cost learning management system.

8.12 References

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SUMMARY

Chapter 1. Gross human anatomy is one of the oldest branches of medical knowledge and can be considered one of the fundamental pillars of medical training. Human anatomy as a science developed significantly from ancient Greece to the 19th century, taking a central role in the evolution of medical sciences. The 20th century began the metamorphosis of anatomical sciences, and several changes occurred in anatomy as a science and in teaching anatomy. Regarding anatomy as a science, medical imaging methods facilitate direct visualization of pathological conditions around anatomical structures and allow the exploration of living anatomy. In the educational field, this has been expressed with technology innovations as teaching strategies or resources, allowing students to learn continuously and adaptively, promoting autonomy, personalization, and the development of digital skills. The requirements of health professional workers to cover health needs have led public medical schools in low—and middle-resource countries to the challenge of providing quality medical training to an increasing number of students but with the same number of, or even fewer, qualified teachers, the same amount of teaching resources, and limited access to education equipment and infrastructure. The growth of science and education health and new challenges in anatomy, such as difficulty in obtaining and maintaining cadavers, the reduction in the number of hours, and the educational trend of promoting applicable knowledge and value in professional practice, led us to investigate:

1. *How can anatomy teaching be optimized?*
2. *How can differences between higher-income countries (HIC) and lower-middle-income countries (LMIC) influence anatomy education?*
3. *How do resource-deprived countries in the Global South uphold the anatomy teaching obligation?*

Question 1 is addressed in chapters 2, 3, and 4; question 2 in chapter 5; and question 3 in chapters 6 and 7.

Chapter 2. In this study, the authors, all with backgrounds in anatomy, radiology, and medical education, conducted structured conversations with 12 academic colleagues with similar backgrounds, reviewed pertinent literature, and analyzed the causes of the historical decline of the knowledge domain of medical education that is nevertheless widely considered essential for medical students and graduates. After this analysis, the authors proposed four ways forward. These directions include systematic peer teaching and developing anatomy education as a scholarly domain, further vertical integration with postgraduate medical education, full integration with radiology education, and capitalizing on educational technology. Schools in several industrialized countries have made steps in these directions, which can be further strengthened.

These steps are less easy to make in less affluent countries and countries with curricula strongly determined by tradition. To respond to changes in global health and

health care, combined with the inevitable technological progress and international mobility, we believe all schools will move in these directions, slower or faster.

Chapter 3. An online learning course in anatomy was added to the regular academic anatomy course in the second year of medicine at UNAN-Leon in Nicaragua using the MOODLE platform. This study aimed to determine the learning effect of this course. Second-year medical students were randomly allocated to an experimental (N=25) and control group (N=50). Only the experimental group had access to the online learning module. We compared the experimental and control groups' performance on regular anatomy assessments and an objective structured practical exam (OSPE). Five focus groups were also interviewed to learn about their experiences with the expanded course.

Of the students in the experimental group, 94.1% and 81.6% of students in the control group took the OSPE. The experimental group significantly outperformed the control group (41.1 ±19.3 points vs. 32.1 ±23.1 points) on the OSPE. No differences between the two groups were found on the regular anatomy examination. Focus group interviews revealed that students ‘opinions about the online course were generally positive.

In general, adding an online course to the regular course was beneficial. The qualitative evaluation results of this intervention provided us with input about how to teach and evaluate the anatomy course and how to improve the online course further to enhance anatomy learning.

Chapter 4. In resource-deprived countries, dissection as a means of teaching anatomy is often not feasible due to the limited availability of bodies, high cost, and safety risks. In Nicaragua, anatomy and radiology education is in an independent format in the medical curriculum. This paper explored the impact (performance and perceptions) of using radiological images in teaching anatomy to medical students from a resource-deprived country.

An extracurricular course in radiologic anatomy of the trunk was implemented for third (n=87) and sixth (n=66) medical students. Pre- and post-tests and a post-course survey were applied. Mean, median, and SD were calculated, with a confidence interval level of 95%.

Perceptions from both groups were similar. Regarding radiological techniques, CT (82.8% junior and 94% senior students) was the most helpful, and ultrasound was the least (49.4% junior and 67.2% senior). Didactic resource acceptance: study guide (73.6% junior and 82.1% senior) and digital-interactive atlas (69% junior and 80.6% senior) got the highest score, while printed books (36.8% junior and 59.7% senior) got the lowest score. The pre-test scores were similar in both groups (the mean of correct

answers was 7.98 junior and 8.22 senior). The mean of correct answers increased in both groups in the post-test: 32.03 for junior and 32.82 for senior students (p=0.000).

Integrating radiology and anatomy positively impacts medical students. It should be implemented through a self-directed learning approach and considered complementary in the medical curriculum as a good alternative for teaching anatomy in countries where dissection is not feasible.

Chapter 5. Despite the universal significance of anatomy education for doctors, there are vast differences in the quantity and nature of anatomy training among cultures and countries. We investigated how Nicaraguan and Dutch medical students perceive and value anatomy education.

Junior and senior medical students from a Nicaraguan and a Dutch university were surveyed with questions about their perception of anatomy education, their preference for teaching methods, and their perspective on learning and teaching anatomy. Each variable was cross-referenced with the academic year of training. Outcomes were compared across universities; a p-value was calculated.

The response rate from Nicaragua was 74% (n=301), and from the Netherlands was 35% (n=215). All students agreed that the quantity of anatomy in their curriculum was satisfactory. Most Nicaraguan students were neutral regarding their appreciation of studying anatomy, while Dutch students generally had a high appreciation. Most Dutch students found the quality of anatomy education satisfactory, while most Nicaraguan students thought anatomy education could improve. Senior students preferred dissection/prosection as an anatomy teaching method, while juniors preferred surgery observation. Few students considered becoming an anatomist as a career.

Dutch students appreciated anatomy education more than Nicaraguan students. All agreed that anatomy is essential but not an exciting career option. Students ´differences in perception seem, at least partly, caused by culture and linked to affluence.

Chapter 6. Teaching anatomy is an essential but expensive part of the medical curriculum, potentially more than many countries can afford. Cost-effectiveness is of utmost importance in the search for efficient methods in such countries. This contribution aimed to review the literature on anatomy teaching methods and evaluate these for feasibility in resource-deprived countries.

A literature review was carried out to identify distinct approaches to anatomy teaching published between 2000 and 2014, using the databases of PubMed, Wiley Online Library, Elsevier, HINARI, Springer, and ERIC. The approaches found were compared against their conceptual, operational, technical, and economic feasibility and Mayer´s principles of effective instruction.

Our search yielded 432 papers that met the inclusion criteria. We identified 14 methods of teaching anatomy. According to their conceptual feasibility, dissection and technology-enhance learning approaches appeared to have more benefits than others. Dissection has, besides benefits, many specific drawbacks. Lectures and peer teaching showed better technical and economic feasibility. Educational platforms, radiological imaging, and lectures showed the highest operational feasibility. Dissection and surgery were found to be less feasible because of operational, technical, and economic characteristics.

Based on our findings, the most important recommendations for anatomy teaching in seriously resource-deprived countries include a combination of complementary strategies at three different moments: lecturing at the beginning, using a virtual learning environment (for self-study), and, at the end, using demonstration through prosected specimens and radiological imaging. This provides reasonable anatomy insights through dead and living human bodies and their virtual representations.

Chapter 7. With limited means, resource-deprived countries must find ways to organize education creatively to meet standards. There are few reports about studies on anatomical education in LLMIC. This study explored how anatomy teaching is sustained in countries with few resources and what affordable educational strategies were applied to uphold quality.

A mixed-method study with anatomy teachers from public medical schools in Africa, Asia, Europe, and Latin-American was performed through a survey via email (n=13) combined with a semi-structured online interview (n=8) with teachers from Zimbabwe, Mozambique, Pakistan, India, Venezuela, and Nicaragua, to explore survey at more profound.

Significant teaching challenges LLMICs face, primarily due to lack of funds, were faculty shortage (low salaries and high student-to-teacher ratio) and inadequate infrastructure (internet, electricity, and poor classroom conditions). Solutions were associated with didactic strategies (e-learning, image-based learning, and applied anatomy), expanding teaching capacity with less qualified and part-time faculty, student-organized education, and self-financing (teaching resources subsidized by teachers and students). Striking was teacher commitment despite difficult circumstances. Their desires and proposals regarded better faculty management, increased anatomy staff recruitment, and collaboration with other institutions.

Anatomical education in LLMIC is forced to adapt to the socio-economic context, not so much to trends in medical education worldwide. These adaptations are supported mainly by the teachers ‘commitment.

Chapter 8. In this chapter, we explained each study's primary results, discussed the approaches to health professional education research and anatomy education, and proposed new research avenues in medical education. Additionally, we developed a critical reflection on the research methodology used.

Traditional classroom teaching has long influenced anatomy education, centered on the teacher, and supported mainly by anatomy textbooks and atlases. Teaching strategies and resources have changed with adopting the constructivist educational approach and the growing use of technology in all areas. The adaptability and efficiency of the Internet have transformed students' approach to self-directed learning, and their preferences have also evolved since they do not depend on books to acquire knowledge. However, information from the Internet can be inaccurate, incomplete, and without a scientific basis; thus, the anatomy teacher's new role is a facilitator and counselor who can examine and filter the information based on their experience and mastery of the subject.

Across our studies, we found that integrating anatomy with radiology offers early and meaningful clinical experiences and bridges the gap between anatomy and clinical medicine. The challenges in LMIC regard (1) resource availability, due to some public hospitals having only X-ray facilities and access to images from other radiological techniques is limited to private clinics or exceptional cases; and (2) educational contexts regarding physical facilities (furniture, air conditioning, equipment) which represents an economic investment and maintenance costs that many medical schools in low-resource countries cannot afford.

We highlighted that medical education literature comes primarily from countries known as the “Global North”. Several factors may contribute to this low percentage of publications by authors from low-income countries (global south) in scientific journals: (1) the power structure of knowledge that is biased and dominated by journal editors from the northern globe; (2) lack of resources or access to Western literature and scientific writing training; (3) language barriers, as not all teachers are fluent in academic English; (4) many medical schools do not allocate budget for research in medical education; and (5) many medical schools in low-income countries suffer from a brain drain of academic staff to developing countries.

Our conclusion is that anatomy is still current and essential in medical sciences; however, it is no longer in the traditional leading role. The change also occurs in the focus of their practice, not so much as science, but more with an educational approach. Given its visual and practical nature, anatomy can be implemented horizontally and vertically (especially in radiology) integration. In academic settings with limited resources, the commitment and motivation of teachers and students are vital to the development of anatomy and all medical sciences. In anatomy, some of the most viable strategies for facing the main challenges are visual learning, applied anatomy, and

using widely available technology such as WhatsApp when the internet or electricity is regularly unavailable.

SAMENVATTING

Hoofdstuk 1. De macroscopische anatomie van de mens is een van de oudste takken van medische wetenschap en kan worden beschouwd als een fundamentele pijler van de medische opleiding. De menselijke anatomie als wetenschap heeft zich aanzienlijk ontwikkeld vanaf het oude Griekenland tot de 19e eeuw en heeft een centrale rol gespeeld in de evolutie van de medische wetenschappen. In de 20e eeuw begon de metamorfose van de anatomische wetenschap, en er vonden verschillende veranderingen plaats in de anatomie als wetenschap en in het onderwijs in de anatomie. Ten gunste van de anatomie als vakgebied hebben medische beeldvormingstechnieken de directe visualisatie van pathologie rond anatomische structuren vergemakkelijkt en maken deze nu de verkenning van de levende anatomie mogelijk. Voor het onderwijs heeft dit bijgedragen aan technologische innovaties ten behoeve onderwijsstrategieën en -methoden, waardoor studenten continu en adaptief kunnen leren, en waardoor autonomie, personalisatie en de ontwikkeling van digitale vaardigheden worden bevorderd. De eisen die gesteld worden aan professionals in de gezondheidszorg, om in de volksgezondheidsbehoeften te voorzien. hebben met name medische opleidingen in openbare universiteiten in lage- en middenkomenslanden gesteld voor de uitdaging om kwalitatief hoogstaand medisch onderwijs te bieden aan een voortdurend groeiend aantal studenten, met een veelal gelijk aantal, of zelfs minder, gekwalificeerde docenten en middelen, en beperkte voorzienigen op het gebied van onderwijsapparatuur en onderwijsinfrastructuur. De groei van wetenschap en onderwijs en uitdagingen op het gebied van de anatomie, zoals moeilijkheded bij het verkrijgen en preserveren van stoffelijke overschotten, de vermindering van onderwijsuren en de wens en behoefte aan grotere toepasbaarheid van kennis in de beroepspraktijk, brachten ons tot de volgende onderzoeksvragen:

1. Hoe kan anatomieonderwijs geoptimaliseerd worden?
2. Hoe beïnvloeden verschillen tussen landen met een hoge inkomens (high-income countries of HIC) en landen met een laag- of middeninkomens (low and middle income countries of LMIC) het anatomieonderwijs?
3. Hoe kunnen landen van de Global South met een sterk tekort aan middelen toch het onderwiijs in de anatomie op peil houden?

Vraag 1 wordt behandeld in de hoofdstukken 2, 3 en 4; vraag 2 in hoofdstuk 5; en vraag 3 in de hoofdstukken 6 en 7.

Hoofdstuk 2. In deze studie voerden de auteurs, allen met een achtergrond in anatomie, radiologie en/of medisch onderwijs, gestructureerde gesprekken met 12 academische collega’s met vergelijkbare achtergronden. Daartoe bestudeerden zijn eerst de relevante literatuur en analyseerden de oorzaken van de historische achteruitgang van het kennisdomein van medisch onderwijs dat niettemin algemeen als essentieel wordt beschouwd voor de medische studie en haar afgestudeerden. Na deze

analyse stelden de auteurs vier ontwikkelingsrichtingen voor: (a) systematische toepassing van *peer-teaching*, in samenhang met de ontwikkeling van anatomieonderwijs als wetenschappelijk domein, (b) verdere verticale integratie met postdoctoraal medisch onderwijs, (c) volledige integratie met radiologieonderwijs en (d) het kapitaliseren op onderwijstechnologie. Medische opleidingen in verscheidene geïndustrialiseerde landen hebben stappen in deze richtingen gezet, die verder kunnen worden veralgemeniseerd en versterkt.

Deze stappen zijn minder gemakkelijk te maken in minder welvarende landen en landen waar de curricula sterk door traditie worden bepaald. Als reactie op veranderingen in de mondiale gezondheidszorg, gecombineerd met de voortgaande technologische vooruitgang en internationale mobiliteit, menen wij dat alle opleidingen zich in deze richtingen zullen gaan ontwikkelen, langzamer of sneller.

Hoofdstuk 3. Een online cursus anatomie werd toegevoegd aan de reguliere academische anatomiecursus in het tweede jaar geneeskunde aan UNAN-Leon in Nicaragua met behulp van het MOODLE-platform. Dit onderzoek had tot doel het leereffect van deze cursus vast te stellen. Tweedejaars geneeskundestudenten werden willekeurig toegewezen aan een experimentele groep (N=25) of een controlegroep (N=50). Alleen de experimentele groep had toegang tot de online leermodule. We vergeleken de prestaties van de experimentele en controlegroepen op reguliere anatomiebeoordelingen en een uitgebrieden toetsing (een Objective Structured Practice Examination of OSPE). Ook werden vijf focusgroepen gehouden om te leren over de ervaringen van studenten met de uitgebreide cursus.

Van de studenten in de experimentele groep legden respectivelijk 94,1% en 81,6% van de studenten in de controlegroep de OSPE af. De experimentele groep presteerde significant beter dan de controlegroep (41,1 ±19,3 punten versus 32,1 ±23,1 punten) op de OSPE. Bij het reguliere anatomie-examen werden geen verschillen tussen beide groepen gevonden. Uit focusgroepinterviews bleek dat de mening van studenten over de online cursus over het algemeen positief was.

Het bleek nuttig om een online cursus aan de reguliere cursus toe te voegen. De kwalitatieve evaluatieresultaten van deze interventie gaven ons input over hoe we de anatomiecursus kunnen geven en evalueren en hoe we de online cursus verder kunnen verbeteren om het leren van anatomie te verbeteren.

Hoofdstuk 4. In landen met gebrek aan middelen is dissectie als methode om anatomie te onderwijzen vaak niet haalbaar, vanwege de beperkte beschikbaarheid van stoffelijk overschotten, de hoge kosten en risico's. In Nicaragua zijn het anatomie- en radiologieonderwijs onafhankelijk opgenomen in het medische curriculum, maar een relatie mogelijk. In deze studie werd de impact (prestaties en percepties) onderzocht

van het gebruik van radiologische beelden bij het onderwijs in anatomie aan medische studenten in een land met beperkte middelen.

Voor de derdejaars (n=87) en zesdejaars (n=66) jaars geneeskundestudenten werd een extracurriculaire cursus radiologische anatomie van de romp georganiseerd. Er werden pre- en posttests en een enquête na de cursus uitgevoerd. Gemiddelde, mediaan en SD werden berekend, met een betrouwbaarheidsinterval van 95%.

De percepties van beide groepen waren vergelijkbaar. Wat betreft radiologische technieken was computertomografie (CT) (meenden 82,8% junior- en 94% senior-studenten) het nuttigst, en echografie het minst (49,4% junior- en 67,2% senior-studenten). Acceptatie van didactische hulpmiddelen: studiehandleiding (73,6% junior en 82,1% senior) en digitaal-interactieve atlas (69% junior en 80,6% senior) kregen de hoogste score, terwijl gedrukte boeken (36,8% junior en 59,7% senior) de laagste score kregen. De pre-testscores waren in beide groepen vergelijkbaar (gemiddelde score 7,98 bij junior- en 8,22 bij seniorstudenten). De gemiddelde score steeg in beide groepen in de natoets naar 32,03 bij junior- en 32,82 bij seniorstudenten (p=0.000).

De integratie van radiologie en anatomie heeft een positieve invloed op medische studenten. Het kan het best worden geïmplementeerd via een self-directed learning benadering en als complementair worden beschouwd in het medische curriculum als een goed alternatief voor het onderwijzen van anatomie in landen waar dissectie niet haalbaar is.

Hoofdstuk 5. Ondanks de universele betekenis van anatomieonderwijs voor artsen zijn er grote verschillen in de kwantiteit en aard van anatomietraining tussen culturen en landen. We onderzochten hoe Nicaraguaanse en Nederlandse geneeskundestudenten anatomieonderwijs ervaren en waarderen.

Junior- en senior geneeskundestudenten van een Nicaraguaanse en een Nederlandse universiteit werden ondervraagd met vragen over hun perceptie van anatomieonderwijs, hun voorkeur voor lesmethoden en hun kijk op het leren en onderwijzen van anatomie. Elke variabele werd vergeleken met hetzelfde academisch jaar van de opleiding. De resultaten werden tussen universiteiten vergeleken.

Het responspercentage in Nicaragua was 74% (n=301), en in Nederland 35% (n=215). Alle studenten waren het erover eens dat de hoeveelheid anatomie in hun curriculum bevredigend was. De meeste Nicaraguaanse studenten oordeelden neutraal over hun waardering voor de studie van de anatomie, terwijl de Nederlandse studenten daar over het algemeen een hogere waardering voor hadden. De meeste Nederlandse studenten vonden de kwaliteit van het anatomieonderwijs bevredigend, meeste Nicaraguaanse studenten vonden het anatomieonderwijs voor betering vatbaar. Senior studenten gaven de voorkeur aan dissectie met prosectie als lesmethode voor anatomie, terwijl junioren de voorkeur gaven observatie van chirurgische toepassing.

Weinig studenten beschouwden anatoom worden als een aantrekkelijke carrièreoptie voor zichzelf.

Nederlandse studenten waardeerden het anatomieonderwijs meer dan Nicaraguaanse studenten. Iedereen was het erover eens dat anatomie essentieel is, maar geen erg opwindende carrièremogelijkheid. De verschillen in perceptie onder studenten lijken, althans gedeeltelijk, te worden veroorzaakt door cultuur en houdeln mogelijk verband met welvaart.

Hoofdstuk 6. Het onderwijzen van anatomie is een essentieel maar duur onderdeel van het medische curriculum, mogelijk meer dan veel landen zich kunnen veroorloven. Kosteneffectiviteit is van het allergrootste belang bij het zoeken naar efficiënte methoden in dergelijke landen. Het doel van deze studie wss om de literatuur over lesmethoden in de anatomie in kaart te brengen en te evalueren op haalbaarheid in landen met beperkte middelen.

Er werd een literatuuronderzoek uitgevoerd om verschillende benaderingen van anatomieonderwijs te identificeren die tussen 2000 en 2014 zijn gepubliceerd, met behulp van de databases van PubMed, Wiley Online Library, Elsevier, HINARI, Springer en ERIC. De gevonden benaderingen werden vergeleken met hun conceptuele, operationele, technische en economische haalbaarheid en gerelateerd aan de bekende principes van Mayer voor effectief onderwijs.

Onze zoektocht leverde 432 artikelen op die voldeden aan de inclusiecriteria. We identificeerden 14 methoden voor het onderwijs in de anatomie. Volgens hun conceptuele haalbaarheid leken dissectie- en technologie-verbeterende leerbenaderingen meer voordelen te hebben dan andere. Dissectie kent naast voordelen ook veel specifieke nadelen. Collegeonderwijs en peer-teaching lieten een betere technische en economische haalbaarheid zien. Educatieve e-platforms, radiologische beeldvorming en colleges vertoonden de hoogste operationele haalbaarheid. Dissectie en integratie met chirurgisch onderwijs bleken minder haalbaar vanwege operationele, technische en economische kenmerken.

Op basis van onze bevindingen omvatten de belangrijkste aanbevelingen voor het anatomieonderwijs in landen met ernstige tekorten een combinatie van complementaire strategieën op drie verschillende manieren: frontaal onderwijs aan het begin, vervolgens inzet van een virtuele, online leeromgeving voor zelfstudie, en uiteindelijk, tenslotte demonstratie door middel van prosectie in combinatie met radiologische beelden. Dit levert redelijke anatomische inzichten op via dode en levende menselijke lichamen en hun virtuele representaties.

Hoofdstuk 7. In landen met beperkte middelen moeten opleidingen op een creatieve manier trachten om aan redelijke kwaliteitsnormen voor anatomisch onderwijs te voldoen. Er zijn weinig rapporten over onderzoeken naar anatomisch onderewijs in

LLMIC (Low and Low-Middle Income Countries). In deze studie onderzochten wij hoe het anatomieonderwijs op niveau wordt gehouden in landen met weinig middelen, en welke betaalbare onderwijsstrategieën werden toegepast.

Een mixed-methods studie onder anatomiedocenten van openbare medische scholen in Afrika, Azië, Europa en Latijns-Amerika werd uitgevoerd via een enquête via e-mail (n=13) gecombineerd met semi-gestructureerd online interviews (n=8) met docenten uit Zimbabwe, Mozambique, Pakistan, India, Venezuela en Nicaragua, om de survey-antwoorden dieper te doorgronden.

Aanzienlijke uitdagingen op het gebied van onderwijs waarmee LLMIC's worden geconfronteerd, voornamelijk als gevolg van een gebrek aan geld, omvatten een tekort aan docenten (lage salarissen en een hoge student-docent ratio) en een ontoereikende infrastructuur (internet, elektriciteit en slechte omstandigheden in onderwijslokalen). Oplossingen werden gezocht met didactische strategieën (e-learning, beeldgebaseerd leren en toegepaste anatomie), het uitbreiden van de onderwijscapaciteit met minder gekwalificeerde en deeltijddocenten, door studenten georganiseerd onderwijs en zelffinanciering (leermiddelen gesubsidieerd door docenten en studenten). Opvallend was de persoonlijke betrokkenheid en inzet van docenten ondanks moeilijke omstandigheden. Gevraagd naar wensen en voorstellen noemden zij een beter faculteitsmanagement, uitbreiding van anatomiepersoneel en meer samenwerking met andere instellingen.

Anatomisch onderwijs in LLMIC wordt gedwongen zich aan te passen aan de sociaal-economische context, en niet zozeer aan trends en ontwikkelingen in het medisch onderwijs wereldwijd. Deze aanpassingen worden opvallend vaak gerealiseerd door de persoonlijke inzet van de docenten.

Hoofdstuk 8. In dit hoofdstuk hebben we de belangrijkste resultaten van elk onderzoek toegelicht, de benaderingen van onderzoek naar professionals in de gezondheidszorg en anatomieonderwijs besproken, en hebben we nieuwe onderzoeks-mogelijkheden in het medisch onderwijs voorgesteld. Daarnaast voerden we een kritische reflectie uit op de gebruikte onderzoeksmethodologie in deze studies. Traditioneel frontaal onderwijs heeft lange tijd gedomineerd in het anatomieonderwijs, waarbij de leraar centraal stond en voornamelijk werd ondersteund door anatomieboeken en atlassen. Onderwijsstrategieën en -middelen zijn veranderd door de adoptie van de constructivistische onderwijsbenaderingen en het toenemende gebruik van technologie op alle gebieden. Het aanpassingsvermogen en de efficiëntie van internet hebben de benadering van studenten ten aanzien van zelfstudie veranderd, en hun voorkeuren zijn ook geëvolueerd omdat ze niet afhankelijk zijn van boeken om kennis te verwerven. Informatie van internet kan echter onnauwkeurig, onvolledig en onwetenschappelijk zijn. De nieuwe rol van de anatomiedocent is dus vooral een

facilitator en adviseur die de informatie kan helpen zoeken en filteren op kwaliteit, op basis van hun ervaring en beheersing van het onderwerp.

In onze studies hebben we ontdekt dat de integratie van anatomie met radiologie vroege en betekenisvolle klinische ervaringen oplevert en de kloof tussen anatomie en klinische geneeskunde overbrugt, mar dat is niet universee.l De uitdagingen in de LMIC hebben betrekking op (1) de beschikbaarheid van middelen, omdat sommige openbare ziekenhuizen alleen beperkte röntgenfaciliteiten hebben en de toegang tot beelden van andere radiologische technieken beperkt is tot privéklinieken of uitzonderlijke gevallen; en (2) onderwijscontexten in de zin van fysieke faciliteiten (meubilair, airconditioning, apparatuur), wat economische investerings- en onderhoudskosten vertegenwoordigt die veel medische scholen in landen met weinig middelen zich niet kunnen veroorloven.

We stelden vast dat literatuur over medisch onderwijs voornamelijk afkomstig is uit landen die bekend staan als de ‘Global North’. Verschillende factoren kunnen bijdragen aan dit lage percentage publicaties van auteurs uit lage-inkomenslanden (the Global South) in wetenschappelijke tijdschriften: (1) de machtsstructuur van kennis die bevooroordeeld en gedomineerd is door tijdschriftredacteuren uit de Global North; (2) gebrek aan middelen of toegang tot westerse literatuur en wetenschappelijke schrijftraining; (3) taalbarrières, aangezien niet alle docenten vloeiend academisch Engels spreken; (4) veel medische scholen wijzen geen budget toe voor onderzoek over het medisch onderwijs; en (5) veel medische scholen in lage-inkomenslanden lijden onder een braindrain van academisch personeel dat vertrekt uit ontwikkelingslanden.

Onze conclusie is dat anatomie nog steeds actueel en essentieel is in de medische wetenschappen; het speelt echter niet langer de traditionele hoofdrol. De verandering vindt ook plaats in de focus van hun praktijk, niet zozeer als wetenschap, maar meer met een educatieve benadering. Gezien het visuele en praktische karakter kan anatomie horizontaal en verticaal (vooral in de radiologie) worden geïntegreerd. In academische omgevingen met beperkte middelen zijn de inzet en motivatie van docenten en studenten van cruciaal belang voor de ontwikkeling van de anatomie en alle medische wetenschappen. Op het gebied van de anatomie zijn enkele van de meest haalbare strategieën om de belangrijkste uitdagingen het hoofd te bieden visueel leren, toegepaste anatomie en het gebruik van algemeen beschikbare technologie, zoals WhatsApp wanneer internet of elektriciteit regelmatig niet beschikbaar zijn.

RESUMEN

Capítulo 1. La anatomía humana macroscópica es una de las ramas más antiguas del conocimiento médico y puede considerarse uno de los pilares fundamentales de la formación médica. La anatomía humana como ciencia se desarrolló significativamente desde la antigua Grecia hasta el siglo XIX, asumiendo un papel central en la evolución de las ciencias médicas. El siglo XX inició la metamorfosis de las ciencias anatómicas y se produjeron varios cambios en la anatomía como ciencia y en la enseñanza de la anatomía. Respecto a la anatomía como ciencia, los métodos de imágenes médicas facilitan la visualización directa de condiciones patológicas alrededor de las estructuras anatómicas y permiten la exploración de la anatomía viva. En el ámbito educativo, esto se ha expresado con las innovaciones tecnológicas como estrategias o recursos didácticos, que permiten a los estudiantes aprender de forma continua y adaptativa, promoviendo la autonomía, la personalización y el desarrollo de habilidades digitales. La necesidad de que los profesionales de la salud cubran las necesidades de salud ha llevado a las escuelas públicas de medicina en países de bajos y medianos recursos al desafío de brindar capacitación médica de calidad a un número cada vez mayor de estudiantes pero con el mismo número de docentes calificados, o incluso menos. , la misma cantidad de recursos didácticos y acceso limitado a equipos e infraestructura educativos. El crecimiento de la ciencia y la educación en salud y los nuevos desafíos en anatomía, como la dificultad en la obtención y mantenimiento de cadáveres, la reducción del número de horas y la tendencia educativa de promover conocimientos aplicables y valor en la práctica profesional, nos llevaron a investigar:

- ¿Cómo se puede optimizar la enseñanza de la anatomía?
- ¿Cómo pueden influir las diferencias entre los países de ingresos altos (PIA) y los países de ingresos medianos bajos (PIMB) en la educación de anatomía?
- ¿Cómo cumplen los países del Sur Global con escasez de recursos la obligación de enseñar anatomía?

La pregunta 1 se aborda en los capítulos 2, 3 y 4; pregunta 2 en el capítulo 5; y la pregunta 3 en los capítulos 6 y 7.

Capítulo 2. En este estudio, los autores, todos con experiencia en anatomía, radiología y educación médica, llevaron a cabo conversaciones estructuradas con 12 colegas académicos con experiencia similar, revisaron la literatura pertinente y analizaron las causas del declive histórico del dominio del conocimiento de educación médica que, sin embargo, se considera ampliamente esencial para los estudiantes y graduados de medicina. Después de este análisis, los autores propusieron cuatro caminos a seguir. Estas direcciones incluyen la enseñanza sistemática entre pares y el desarrollo de la educación en anatomía como un dominio académico, una mayor integración vertical con la educación médica de posgrado, la integración total con la educación en radiología y la capitalización de la tecnología educativa. Las escuelas de

varios países industrializados han dado pasos en esta dirección, que pueden reforzarse aún más.

Estos pasos son menos fáciles de dar en los países menos ricos y en los países con planes de estudios fuertemente determinados por la tradición. Para responder a los cambios en la salud y la atención médica globales, combinados con el inevitable progreso tecnológico y la movilidad internacional, creemos que todas las escuelas avanzarán en estas direcciones, más lento o más rápido.

Capítulo 3. Se agregó un curso de aprendizaje en línea de anatomía al curso académico regular de anatomía del segundo año de medicina de la UNAN-León en Nicaragua utilizando la plataforma MOODLE. Este estudio tuvo como objetivo determinar el efecto de aprendizaje de este curso. Los estudiantes de medicina de segundo año fueron asignados aleatoriamente a un grupo experimental (N=25) y un grupo de control (N=50). Sólo el grupo experimental tuvo acceso al módulo de aprendizaje en línea. Comparamos el desempeño de los grupos experimental y de control en evaluaciones periódicas de anatomía y un examen práctico objetivo estructurado (OSPE). También se entrevistó a cinco grupos focales para conocer sus experiencias con el curso ampliado.

De los estudiantes del grupo experimental, el 94,1% y el 81,6% de los estudiantes del grupo control tomaron la OSPE. El grupo experimental superó significativamente al grupo de control (41,1 ±19,3 puntos frente a 32,1 ±23,1 puntos) en la OSPE. No se encontraron diferencias entre los dos grupos en el examen anatómico regular. Las entrevistas de los grupos focales revelaron que las opiniones de los estudiantes sobre el curso en línea fueron en general positivas.

En general, agregar un curso en línea al curso regular fue beneficioso. Los resultados de la evaluación cualitativa de esta intervención nos brindaron información sobre cómo enseñar y evaluar el curso de anatomía y cómo mejorar aún más el curso en línea para mejorar el aprendizaje de la anatomía.

Capítulo 4. En países privados de recursos, la disección como medio para enseñar anatomía a menudo no es factible debido a la disponibilidad limitada de cuerpos, el alto costo y los riesgos para la seguridad. En Nicaragua, la educación en anatomía y radiología tiene un formato independiente en el plan de estudios de medicina. Este artículo exploró el impacto (rendimiento y percepciones) del uso de imágenes radiológicas en la enseñanza de anatomía a estudiantes de medicina de un país privado de recursos.

Se implementó un curso extracurricular de anatomía radiológica del tronco para estudiantes de tercer (n=87) y sexto (n=66) de medicina. Se aplicaron pruebas previas y posteriores y una encuesta posterior al curso. Se calcularon la media, la mediana y la DE, con un nivel de intervalo de confianza del 95%.

Las percepciones de ambos grupos fueron similares. En cuanto a las técnicas radiológicas, la TC (82,8% junior y 94% senior) fue la de mayor utilidad y la ecografía la de menor utilidad (49,4% junior y 67,2% senior). Aceptación de recursos didácticos: la guía de estudio (73,6% junior y 82,1% senior) y el atlas digital interactivo (69% junior y 80,6% senior) obtuvieron la puntuación más alta, mientras que los libros impresos (36,8% junior y 59,7% senior) obtuvieron la puntuación más baja. . Las puntuaciones del pretest fueron similares en ambos grupos (la media de respuestas correctas fue 7,98 junior y 8,22 senior). La media de respuestas correctas aumentó en ambos grupos en el post-test: 32,03 para los estudiantes de junior y 32,82 para los de senior (p=0,000).

La integración de radiología y anatomía impacta positivamente a los estudiantes de medicina. Debe implementarse mediante un enfoque de aprendizaje autodirigido y considerarse complementario en el plan de estudios de medicina como una buena alternativa para enseñar anatomía en países donde la disección no es factible.

Capítulo 5. A pesar de la importancia universal de la educación en anatomía para los médicos, existen grandes diferencias en la cantidad y naturaleza de la formación en anatomía entre culturas y países. Investigamos cómo los estudiantes de medicina nicaragüenses y holandeses perciben y valoran la educación en anatomía.

Se encuestó a estudiantes de medicina de tercer y cuarto año de una universidad nicaragüense y holandesa con preguntas sobre su percepción de la educación en anatomía, su preferencia por los métodos de enseñanza y su perspectiva sobre el aprendizaje y la enseñanza de la anatomía. Cada variable se cruzó con el año académico de formación. Se compararon los resultados entre universidades; Se calculó un valor p.

La tasa de respuesta de Nicaragua fue del 74% (n=301) y de los Países Bajos fue del 35% (n=215). Todos los estudiantes estuvieron de acuerdo en que la cantidad de anatomía en su plan de estudios era satisfactoria. La mayoría de los estudiantes nicaragüenses fueron neutrales en cuanto a su apreciación por el estudio de la anatomía, mientras que los estudiantes holandeses en general tuvieron una alta apreciación. La mayoría de los estudiantes holandeses consideraron satisfactoria la calidad de la educación en anatomía, mientras que la mayoría de los estudiantes nicaragüenses pensaron que la educación en anatomía podría mejorar. Los estudiantes de último año prefirieron la disección/prosección como método de enseñanza de anatomía, mientras que los de tercer año prefirieron la observación quirúrgica. Pocos estudiantes consideraban convertirse en anatomista como carrera.

Los estudiantes holandeses valoraron más la educación en anatomía que los estudiantes nicaragüenses. Todos estuvieron de acuerdo en que la anatomía es esencial pero no una opción profesional apasionante. Las diferencias de percepción de

los estudiantes parecen, al menos en parte, causadas por la cultura y vinculadas a la riqueza.

Capítulo 6. La enseñanza de anatomía es una parte esencial pero costosa del plan de estudios de medicina, potencialmente más de lo que muchos países pueden permitirse. La rentabilidad es de suma importancia en la búsqueda de métodos eficientes en dichos países. Esta contribución tuvo como objetivo revisar la literatura sobre métodos de enseñanza de anatomía y evaluar su viabilidad en países de escasos recursos.

Se llevó a cabo una revisión de la literatura para identificar distintos enfoques para la enseñanza de la anatomía publicados entre 2000 y 2014, utilizando las bases de datos de PubMed, Wiley Online Library, Elsevier, HINARI, Springer y ERIC. Los enfoques encontrados se compararon con su viabilidad conceptual, operativa, técnica y económica y los principios de instrucción efectiva de Mayer.

Nuestra búsqueda arrojó 432 artículos que cumplieron con los criterios de inclusión. Identificamos 14 métodos de enseñanza de la anatomía. Según su viabilidad conceptual, los enfoques de disección y aprendizaje mejorado por tecnología parecieron tener más beneficios que otros. La disección tiene, además de beneficios, muchos inconvenientes específicos. Las conferencias y la enseñanza entre pares mostraron una mayor viabilidad técnica y económica. Las plataformas educativas, las imágenes radiológicas y las conferencias mostraron la mayor viabilidad operativa. Se encontró que la disección y la cirugía eran menos factibles debido a las características operativas, técnicas y económicas.

Según nuestros hallazgos, las recomendaciones más importantes para la enseñanza de anatomía en países gravemente privados de recursos incluyen una combinación de estrategias complementarias en tres momentos diferentes: dar una conferencia al principio, utilizar un entorno de aprendizaje virtual (para el autoestudio) y, al final. Para finalizar, mediante la demostración mediante muestras proseccionadas e imágenes radiológicas. Esto proporciona una visión razonable de la anatomía a través de cuerpos humanos vivos y muertos y sus representaciones virtuales.

Capítulo 7. Con medios limitados, los países privados de recursos deben encontrar formas de organizar la educación de manera creativa para cumplir con los estándares. Hay pocos informes sobre estudios sobre educación anatómica en LLMIC. Este estudio exploró cómo se sostiene la enseñanza de la anatomía en países con pocos recursos y qué estrategias educativas asequibles se aplicaron para mantener la calidad.

Se realizó un estudio de método mixto con profesores de anatomía de escuelas públicas de medicina de África, Asia, Europa y América Latina mediante una encuesta vía correo electrónico (n=13) combinada con una entrevista semiestructurada en línea

(n=8) con profesores. de Zimbabwe, Mozambique, Pakistán, India, Venezuela y Nicaragua, para explorar la encuesta en mayor profundidad.

Los importantes desafíos docentes que enfrentan los LLMIC, principalmente debido a la falta de fondos, fueron la escasez de docentes (bajos salarios y alta proporción de estudiantes por maestro) y una infraestructura inadecuada (Internet, electricidad y malas condiciones en las aulas). Las soluciones se asociaron con estrategias didácticas (e-learning, aprendizaje basado en imágenes y anatomía aplicada), la ampliación de la capacidad docente con profesores menos calificados y a tiempo parcial, la educación organizada por los estudiantes y el autofinanciamiento (recursos didácticos subsidiados por profesores y estudiantes).). Lo sorprendente fue el compromiso de los docentes a pesar de las circunstancias difíciles. Sus deseos y propuestas contemplaban una mejor gestión del profesorado, una mayor contratación de personal de anatomía y la colaboración con otras instituciones.

La educación anatómica en los LLMIC se ve obligada a adaptarse al contexto socioeconómico, no tanto a las tendencias de la educación médica en todo el mundo. Estas adaptaciones se sustentan principalmente en el compromiso de los docentes.

Capítulo 8. En este capítulo, explicamos los resultados principales de cada estudio, discutimos los enfoques para la investigación en educación de profesionales de la salud y la educación en anatomía, y propusimos nuevas vías de investigación en educación médica. Además, desarrollamos una reflexión crítica sobre la metodología de investigación utilizada.

La enseñanza conductista ha influido durante mucho tiempo en la educación de la anatomía, centrada en el profesor y apoyada principalmente por libros de texto y atlas de anatomía. Las estrategias y recursos didácticos han cambiado con la adopción del enfoque educativo constructivista y el creciente uso de la tecnología en todos los ámbitos. La adaptabilidad y eficiencia de Internet han transformado el enfoque de los estudiantes hacia el aprendizaje autodirigido, y sus preferencias también han evolucionado al no depender de libros para adquirir conocimientos. Sin embargo, la información de Internet puede ser inexacta, incompleta y sin base científica; así, el nuevo rol del profesor de anatomía es el de facilitador y consejero que puede examinar y filtrar la información en función de su experiencia y dominio del tema.

A lo largo de nuestros estudios, descubrimos que la integración de la anatomía con la radiología ofrece experiencias clínicas tempranas y significativas y cierra la brecha entre la anatomía y la medicina clínica. Los desafíos en los países de ingresos bajos y medianos tienen que ver con (1) la disponibilidad de recursos, debido a que algunos hospitales públicos solo tienen instalaciones de rayos X y el acceso a imágenes de otras técnicas radiológicas está limitado a clínicas privadas o casos excepcionales; y (2) contextos educativos relacionados con las instalaciones físicas (mobiliario, aire acondicionado, equipos) que representan una inversión económica y

costos de mantenimiento que muchas facultades de medicina en países de bajos recursos no pueden afrontar.

Destacamos que la literatura sobre educación médica proviene principalmente de países conocidos como el “Norte Global”. Varios factores pueden contribuir a este bajo porcentaje de publicaciones de autores de países de bajos ingresos (sur global) en revistas científicas: (1) la estructura de poder del conocimiento que está sesgada y dominada por editores de revistas del mundo norte; (2) falta de recursos o acceso a la literatura occidental y a la formación en redacción científica; (3) barreras del idioma, ya que no todos los profesores dominan el inglés académico; (4) muchas facultades de medicina no asignan presupuesto para la investigación en educación médica; y (5) muchas facultades de medicina en países de bajos ingresos sufren una fuga de cerebros de personal académico hacia los países en desarrollo.

Nuestra conclusión es que la anatomía sigue siendo actual e imprescindible en las ciencias médicas; sin embargo, ya no desempeña el papel protagónico tradicional. El cambio también se da en el enfoque de su práctica, no tanto como ciencia, sino más con un enfoque educativo. Dada su naturaleza visual y práctica, la anatomía se puede implementar de forma integrada horizontal y vertical (especialmente en radiología). En entornos académicos con recursos limitados, el compromiso y la motivación de profesores y estudiantes son vitales para el desarrollo de la anatomía y de todas las ciencias médicas. En anatomía, algunas de las estrategias más viables para enfrentar los principales desafíos son el aprendizaje visual, la anatomía aplicada y el uso de tecnologías ampliamente disponibles como WhatsApp cuando Internet o la electricidad no están disponibles regularmente.

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"*Success shared is multiplied; there is no point in reaching very high if you are alone…*"
My journey to success has been a collective effort, a testament to the power of shared experiences. The path has been extended, marked by significant highs and challenging lows. I am deeply grateful for the invaluable help, guidance, company, and support of the many individuals who have shared this achievement with me.

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Dr. Ronald Bleys. I felt so identified with him, perhaps because we shared a passion for anatomy. I think he always understood my anatomist mind; with him, I didn't need many words for him to understand what I wanted to say. I want to highlight that meeting him meant, at least for me, a paradigm shift regarding the anatomy teacher. I

was pleasantly surprised that he was not the “typical” or “traditional” anatomy teacher. On the contrary, his creativity in explaining anatomy, his joyful spirit, his empathy, and his passion for rock made me realize that the image of anatomy teachers needed to be softened.

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CURRICULUM VITAE

Ana Yoe Cheng Chang Chan

(Academic Medical Doctor)

Professional resume

I am an academic medical doctor from Nicaragua with 20 years of experience in medical education and 24 years in teaching human anatomy, starting when I was an assistant student in anatomy for four years. My career goals are to:

- Contribute to medical education at both the undergraduate and postgraduate levels.
- Strengthen scientific and educational research related to medical education.
- Promote good teaching and medical practices that help train health professionals with quality and warmth.

Academic training

- Master's/MsC. Higher Health Education. National Autonomous University of Nicaragua, León, Nicaragua.
- Master's/MSc in Morphological Sciences and Cell Biology, National Autonomous University of Nicaragua, León, Nicaragua.
- Diploma/Postgraduate. Clinical pharmacology. Antonio Lenin Fonseca School Hospital. American University (UAM), Managua, Nicaragua.
- Doctor of Medicine and Surgery (General Physician). National Autonomous University of Nicaragua, León, Nicaragua.

Other courses/certifications

- Learning Counselor training course for virtual pedagogical mediation. Pan American Health Organization (PAHO), Nicaragua.
- Tutor training course for online learning. Pan American Health Organization (PAHO), Nicaragua.
- Management and Leadership Course with Emphasis on the Learn, Undertake, and Prosper program. National Autonomous University of Nicaragua, León, Nicaragua.
- Training Course on Incorporation of Distance Education in Higher Education. Inter-American Training Network in Education and Telematics, College of the Americas, Inter-American University Organization
- Expert Certificate. Development of Multimedia Teaching Resources for Virtual Education. National Council of Universities-CNU. Managua Nicaragua.

Work experience

1. Pan American Health Organization (PAHO) – Nicaragua (2019 – 2024). Independent consultor

Functions:

- Academic coordination: continuing education courses, developing self-training courses, giving advice and feedback to experts, and lecturing in permanent health education courses.
- Teaching and pedagogical mediation (virtual tutor and workshop facilitator).
- Content creator: develop pedagogical designs, review and update pedagogical designs, interactive presentations, study and learning activity guides, learning evaluation matrices, and educational content videos.
- Technical support in the drafting and writing (in English and Spanish) of country projects for the Pandemic Fund call.

2. National Autonomous University of Nicaragua. UNAN-León. (2004 – 2022). Professor.

Functions:

- Coordination: research projects, master's modules, Academic Management Unit of the Department of Virtual Education, Human Anatomy Area of the Department of Morphological Sciences, Student Assistants of Anatomy and Virtual Education, continuing education programs for teachers, interim head from the Department of Morphological Sciences.
- Teaching and pedagogical mediation: Human Anatomy, Problem-Based Learning (PBL), Medical Skills, undergraduate and graduate academic programs.
- Methodological advice and reviews: undergraduate and graduate scientific works, jury evaluation of undergraduate theses, and preparation of academic-scientific manuscripts by experts.
- Speaker: lectures as an expert in continuing education courses in medical, virtual, and permanent health education.
- Generation of manuscripts: academic and technical reports on projects, programs, and curricular documents (programs and methodological guides for courses and components).
- Intern (1997 – 2000). Assistant student of Human Anatomy in the Department of Morphological Sciences of the Faculty of Medical Sciences.

3. Technological Institute of Internet Studies. TEC-Virtual. Nicaragua. (2018). Instructional Designer.

Functions: Design, assembly, and configuration of virtual courses on Industrial Hygiene and Safety.

4. Redémptoris Mater Catholic University (UNICA). Managua Nicaragua. (2005 – 2008) Associate Professor.
Functions: Design and implement the course. Acquire skills in dissection techniques and prepare human cadavers.

5. Private Medical Services of the Oscar Danilo Rosales Argüello School Hospital (HEODRA). Leon, Nicaragua. (2004) Healthcare physician.
Functions: Medical assistance to workers affiliated with Social Security (INSS) and medical shifts in the Emergency area.

Social Security Pension Medical Company "La Salud". Leon Nicaragua. (2003). Healthcare physician.
Functions: Medical assistance to workers affiliated with Social Security (INSS) and medical shifts in the Emergency area.

Publications

- Chang Chan, Ana Yoe Cheng; van Leeuwen, Maarten Simon; Custers, Eugene; Bleys, Ronald; ten Cate, Olle. Anatomy Education in Low-Resourced Countries: What Are Challenges and Effective and Affordable Educational Strategies? (submitted)
- Chang Chan AYC, Stapper C, Bleys RLAW, van Leeuwen M, ten Cate O. Are we facing the end of gross anatomy teaching as we have known it for centuries? Advances in Medical Education and Practice 2022:13 1243–1250
- Chang AY-C., Mejía L, Chavarría E, Sotelo N, Robles D. Radiological anatomy as an alternative approach in anatomy teaching. Perception and performance of medical students. Inv. Ed Med., 2021; 11(41): 26 - 34. http://www.riem.facmed.unam.mx:90/ojs/index.php/riem
- Chang Chan AYC, ten Cate O, Wammes E, Custers E, van Leeuwen MS; Bleys R. Comparing Medical Student Interest In Gross Anatomy Learning and Teaching Across Different Cultures. Journal of Medical Education and Training 2020; 4:050
- Chang Chan AY, ten Cate O, Custers EJFM, van Leeuwen MS, Bleys RLAW. Approaches of anatomy teaching for seriously resource-deprived countries: a literature review. Education for Health 2019;32(2):62-74
- Chang Chan AYC, Custers E, van Leeuwen M, Bleys R, ten Cate O. Does an online anatomy course improve the performance of medical students on gross anatomy examinations? Medical Science Educator 2019;29(3):697-707
- Chang AY-C, Jirón H, Mejía K. Percepción de los estudiantes sobre la educación en línea en Nicaragua Perception of students about e-learning in Nicaragua. Revista Congreso Universidad. 2018;7(4):166–78. ISSN 2306-918X. Available in: http://revista.congresouniversidad.cu/index.php/rcu/article/view/1064
- Paredes EM, Venegas Y, Moreira MJ, Calvo L, Solano M, Chang AY-C, et al. Prevalencia de la mutación C677T del gen de la metilen Tetrahidrofolato Reductasa en los estudiantes de Medicina de la Facultad de Ciencias Médicas de la Universidad Nacional Autónoma de León, Nicaragua. Rev Clínica Esc Med UCR-HSJD. 2013;3(6). http://repositorio.ucr.ac.cr/handle/10669/14806