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REVIEW

Designing courses in anatomy

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SUMMARY

Medical school has changed. Curricula have become more integrated, more systems based and the teaching of anatomy more clinically relevant. Notwithstanding the efforts by the Anatomical Society to define the "core curriculum", the difficulty lies in ensuring that what is being taught in the anatomy class is not only relevant to clinical training but is vertically integrated with it across the whole academic programme of studies. Deciding what to leave out, while maintaining standards has become very difficult indeed.

Yet the purpose of teaching anatomy must surely lie in its clinical application. As teachers, our goal is to light the fire under our students, in such a way as to stimulate them to look for the answers to common clinical problems for which a knowledge of anatomy is essential. This increasing emphasis on learning within context is particularly important for adult learners, which one would expect most of our students to be.

Cadaver dissection and/or examination of prosected material remains at the core of anatomy learning, because the learning, and perhaps more importantly, the recall of anatomy, is based on the twin principles of observation and visualization.

Deeper learning of key principles and clinically-relevant anatomy requires students to assess themselves regularly. At a time when increasing numbers of atlases and textbooks are being published, those that stand out include study and review questions and answers as opportunities for self- assessment.

The visible and palpable anatomy that forms the basis of clinical examination can only be learned through practice on normal subjects, usually fellow students and oneself. The design of an anatomy course must include opportunities for students to do this under supervision. Correlating these features with imaging studies further enhances deeper learning.

Key words: Anatomy – Teaching – Instructional Design – Curriculum

INTRODUCTION

Anatomy is important in almost everything we do in medicine. It is the basis of clinical examination, and also of the increasingly important diagnostic technologies which enable imaging of the living body, such as ultrasonography, CT scanning, NMR, fMRI, and virtual 3D reconstruction. Anatomy for surgery is paradoxically the least important. Nevertheless, forgetting (or worst still, never knowing) the path of the accessory nerve in the posterior triangle of the neck while excising a sebaceous cyst may have unintended consequences. Whether it is the "safe" location for an intramuscular injection or the interpretation of the Psoas muscle stretch, knowledge of the underlying anatomy is essential.

Anatomy remains the constant and consistent bridge between basic biomedical sciences and clinical medicine. Most patients would expect medical doctors to have a thorough knowledge of anatomy. They would be surprised to find in many medical schools the interactive 3-D animation has replaced the hands-on examination and dissection of cadavers anatomy lab. Quite apart from the actual learning of anatomy, this hands-on approach teaches "real world anatomy" (Miller et al., 2002).

Controversy over medical curricula has developed to the point that the importance of gross anatomy in the medical curriculum is being disputed. Nevertheless, the great majority (98%) of 112 professional anatomists surveyed by Patel and

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Moxham in 2006 reported that gross anatomy has an important role to play in clinical medicine. Although this statistic might seem self-evident, Moxham and Plaisant (2007) also examined the perception of medical students at Cardiff and Paris towards the importance of gross anatomy to clinical medicine. This was undertaken when they were about to start their anatomy courses, immediately after finishing, and in the final year of studies. The results suggest that, even where there might be geopolitical and cultural backgrounds, students at all stages of their medical course share with professional anatomists the view that anatomy is a very important subject for their clinical studies.

In the past, anatomy dominated the undergraduate curriculum with all the details it could muster. Has the pendulum swung too much in the opposite direction? We believe that undergraduate training must deliver junior doctors with sufficient anatomical knowledge and skills to embark on any speciality. However, there is considerable variation in anatomical teaching for medical students not only from one country to another but paradoxically also from one university to another within same country (Chirculescu et al., 2007).

What is a Curriculum?

A curriculum is defined in the following ways:

1. The courses offered by an educational institution;
2. A set of courses constituting an area of specialization (http://www.merriam-webster.com/dictionary/curriculum, accessed 11/3/13)
3. The subjects comprising a course of study in a school or college (http://oxforddictionaries.com/definition/english/curriculum, accessed 11/3/13)

However, the wider view of a curriculum as described by Harden (1986) is about what should happen in a teaching program. This includes the learning outcomes of what is taught, the order in which it is taught, the instructional methods used and how students will be assessed. Gone are the days where designing a curriculum was simply a matter of dividing up the available time between departments, each lobbying (hard) for a greater share of the tabula rasa! Although there is still probably a place for at least a small "inspirational" component in a gross anatomy curriculum, allowing lecturers to teach whatever happens to interest them, is thankfully a thing of the past.

Modern pedagogy requires careful planning of the teaching and learning programme. Planning typically starts by identifying the needs of the programme and establishing the learning outcomes. Medical school is perhaps unique in that design of its courses should consider the needs of patients as well as students. What do patients (and other professionals) expect of their doctors in terms of their anatomical knowledge? Whether a patient cares if a junior doctor knows the relations of the recurrent laryngeal nerve in the neck is debatable, but the ability to think "visually" ie, to "see or feel" through layers of skin, fat, fascia, muscles, etc., to assess a clinical situation requires an understanding of the underlying anatomy. Similarly, patients would expect doctors to be able to reason through visualising 3-dimensional anatomical relationships. Paradoxically, our reliance on computed tomography (CT) and magnetic resonance imaging (MRI) should be reflected in greater emphasis on anatomy today than in the past. Yet in most medical schools the opposite seems to be the case.

EXISTING CURRICULUM MODELS

Dent and Harden (2005) describe a number of different curriculum models, which indeed may coexist. These include outcome-based, problem-based, task-based, integrated systems-based and spiral curricula. Most medical schools utilize a combination of one or more of these models for different parts of their course. Many students select which medical school to apply to depending on the type of curriculum offered. There is some evidence from the US where all medical students take a common exit exam, that notwithstanding the variety of curricula on offer, the pass rate of Step 1 USMLE (basic sciences) is very similar across medical schools, suggesting that there may be more than one way to skin a cat (Swanson et al., 1992; Case et al., 1996; Enarson and Cariaga-Lo, 2001). In an ideal world, each medical school would create flexible learning opportunities and adapt them to the individual students' learning styles. In effect, this is already happening in most institutions that offer a variety of anatomy learning opportunities. Although students are encouraged to attend all of them, most students select which sessions to attend depending on their preferred learning style.

The concept of the "declared", the "taught" and the "learned" curriculum ie what we say we are going to teach as compared to what we actually do teach and what students learn, raises the issue of the "hidden" curriculum ie the informal learning which is unrelated to what we teach. For example, students in our institution are encouraged to attend autopsies as a way of bringing their anatomical knowledge together. Although emotionally challenging, among other things, this experience teaches students to perceive the body as a patient rather than a biological specimen (Weurlander et al., 2012).

1. IDENTIFYING CURRICULUM NEEDS

Dunn et al. (1985) described a number of different ways to identify the competencies expected of junior doctors. These range from consensus among seniors from different specialties, consultation with stakeholders, analysis of critical incidents and practice errors, task analysis and the assessment of the competencies of exceptional doctors. The first two of these are most relevant to the identification of the needs of a gross anatomy curriculum. Indeed, as member of a Delphi panel, the TEPARG group has been actively involved in the process of defining a core syllabus for neuroanatomy, together with clinicians who rely on neuroanatomy (such as neurologists and neurosurgeons).

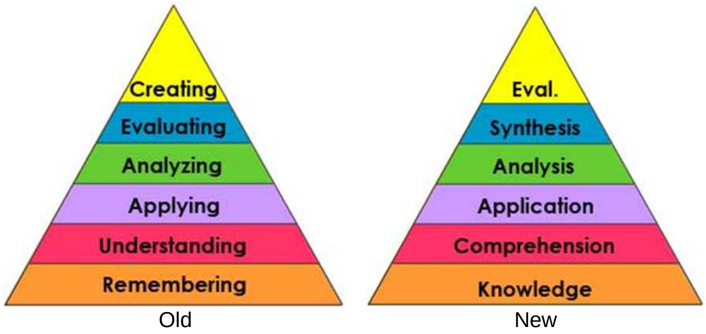

Fig. 1. Bloom's Taxonomy revised. (http://ww2.odu.edu/educ/roverbau/Bloom/blooms_taxonomy.htm)

2. ESTABLISH LEARNING OUTCOMES

An outcome-based anatomical education begins by defining the learning outcomes. Decisions about the content, delivery, assessment and management of the curriculum will then be based on these learning outcomes (Harden et al., 1999). In this model, curriculum planning (and hence student learning) is driven by learning outcomes rather than discipline-specific bodies of knowledge.

This outcome-based model, often described as "planning backwards" begins by defining what sort of doctor is needed, e.g., what are the characteristic traits of the safe doctor. This is followed by designing tests to identify whether students have achieved these outcomes and finally creating appropriate learning experiences to enable students to achieve these outcomes. So for example, if we want to create a doctor who is able to apply anatomical knowledge to practical situations with well-developed problem solving skills, then these are the learning outcomes that should influence what is taught, how it is taught and how it is assessed. This so called competency-based model is contrasted with the more traditional Flexnerian "planning forwards" model which starts by defining the knowledge, imparting it to students, and then testing them. The underlying premise of the "planning forwards" approach is that accumulation of anatomical knowledge will automatically lead to students becoming safe doctors.

Institutions may choose to develop their own learning outcomes or they may adopt one of the existing published ones such as that of Simpson et al. (2002) who categorised the learning outcomes for the medical undergraduate in Scotland into three groups: (1) What the doctor is able to do; (2) How the doctor approaches their practice; and (3) The doctor as a professional. Applying this to a gross anatomy curriculum, and considering for example the clinical skill of abdominal examination, the first step in an outcome-based anatomical curriculum would be to create a full definition. For example, one part of the definition might be that the student is able to describe the surface markings of the liver, kidneys and spleen. This is followed by developing tasks that the student is expected to successfully complete in order to demonstrate competency. Based on the principle that assessment is one of the factors that drives learning, the next step is to create assessments that help students to learn. One of the advantages of this approach is that it allows students to demonstrate increased competency in the area as they progress through the course. Using the above example, a novice would be expected to draw the surface markings of the liver, while an advanced student should be able to utilize this information to safely conduct a liver biopsy and predict possible complications based on anatomical relations.

This approach is in contrast to the more traditional one of creating exhaustive lists of learning objectives and making them available to students, on the assumption that these will guide students as they filter through what is being taught to determine what they actually need to know to pass the final exam. However, not only are learning objectives time consuming to develop, they are quite often (at least in our institution) almost totally ignored when it comes to decisions about what is taught, how it is taught and what is assessed.

Bloom's 1956 classification of levels of intellectual (cognitive) behavior important in learning was updated in the 90s. The new version replaces knowledge at the base of the triangle with remembering, and progresses through understanding, applying and analyzing as in the original version. The top two levels of synthesis and evaluation are essentially reversed in the new version with creation and evaluation respectively. This makes the top tier the process of generating, planning or creating a coherent whole new product from the elements provided (Krathwohl, 2001) (Fig. 1: Bloom's Taxonomy revised).

Applying Bloom's taxonomy to anatomical assessment (of say the upper limb) might range from:

1. Remembering: Name the attachment of the flexor retinaculum.
2. Understanding: Explain in anatomical terms why sensation over the palm of the hand is intact in Carpal Tunnel Syndrome.
3. Applying: What questions can you ask to distinguish between a median nerve injury at the elbow and wrist?

4. Analysing: In what ways do the claw hand in a median nerve and ulnar nerve lesion differ?
5. Evaluating: What are the consequences of a fracture of the neck of the humerus?
6. Creating: What tools could be used to evaluate the severity of a brachial plexus injury?
7. When skills are involved, Miller's triangle may be used to define the learning outcomes (Fig. 2: Miller's Triangle).

In terms of anatomy these might for example be expressed as:
- Know what the boundaries of the inguinal canal are.
- Knows how to palpate the femoral pulse.
- Shows how to obtain an arterial blood sample
- Does: Successfully obtains an arterial blood sample.

3. DECIDE ON CONTENT

Information overload is the bane of student life. It stifles reasoning and curiosity, limits the time available for acquisition of other key competencies and most importantly, results in poor preparation for clinical practice.

The MD degree curriculum has, over the years, "exploded". There is now much more basic and social science for students to learn, but no increase in the time available to learn it. This exponential growth in the scientific component of the curriculum coupled with the understandable need to embrace a more holistic dimension (such as communication skills, ethics, evidence-based practice, teamwork, etc.) to preparing doctors for the future, has led curriculum planners to focus more on core/essential/important anatomical facts (e.g., the surface markings of the internal jugular) and less on the inspirational (e.g., all the branches of the internal iliac artery). However, as new material is added to the curriculum decade after decade, there remains great reluctance to remove detail, particularly in the less clinically relevant anatomical sub specialties. Hence, the eternal conflict between "need to know" and "nice to know".

Most anatomy tutors over the age of 50 in Britain (and its ex-colonies) were themselves taught in

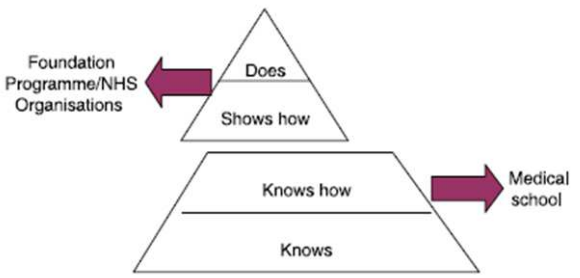

Fig. 2. Miller's Triangle. Adapted from Lai et al. (http://pharmacyeducation.fip.org/2007/12/mindful-of-the-gap-a-process-for-delivering-better-medical-prescribing/)

traditional anatomy courses using the original Gray's Anatomy textbook. On a personal note, many of my medical colleagues who did not specialize in OB/Gyn or Surgery still feel disillusioned because so much of their time at medical school had been wasted on rote recall of irrelevant anatomical and biochemical detail, especially in the early years. Has the pendulum swung too much in the opposite direction? How will the doctors of today caring for yesterday's teachers as they age, look back over their anatomy curriculum? Will they be grateful to modern curriculum developers for removing the unnecessary detail? Will they have realized by then that in order to apply an anatomical base to clinical situations, you first need to acquire, and then retain the relevant knowledge?

Notwithstanding the efforts by the Anatomical Society (http://www.anatsoc.org.uk/Education/CoreCurriculum.aspx) to reduce over-burdening by defining the core anatomical syllabus, many medical schools, especially outside the UK still have difficulty in lowering their expectations of what students should know, at least in the first one to two years of training (Chirculescu et al., 2007).

Take for example Head and Neck 26: Describe the stages of swallowing and the function of the muscles of the jaw, cheek, lips, tongue, soft palate, pharynx, larynx and oesophagus. In our institution, this means knowing the attachments of all of these muscles and being able to describe in detail what each set of muscles is doing during each stage of the process. This question has been asked in recent anatomy exams in our institution and the answer would fill several pages. One doubts that this is what the Educational Committee of the Anatomical Society of Great Britain and Ireland had in mind! The common sense part of the equation is often lost in translation.

This raises the question of who decides what is core (anatomical knowledge)? National regulatory bodies? Professional associations with vested interest, such as the Anatomical Society of Great Britain and Ireland and the American Association of Anatomists, among others? Or should this unenvious task be delegated to individual medical schools or indeed to individual departments of anatomy? Do we all need to re-invent the wheel or can we agree to use a common set of standards as proposed (but clearly not imposed) by the authors of the Anatomical Society's Core Syllabus? In Tomorrow's Doctors (2003), the GMC states that "the core curriculum must be the responsibility of clinicians, basic scientists and medical educationalists working together to integrate their contributions and achieve a common purpose". Most medical schools now devolve responsibility for decisions regarding curriculum content and organization to central committees, particularly when the curriculum design is integrated across disciplines.

We should also take into account the limitations of any exercise in developing a common core syllabus, such as any unintended bias of the stakeholders, institutional ownership, and overall balance between “need to know” and “common sense”, as emphasised by the Anatomical Society of Great Britain and Ireland. Just as the shoulder sacrifices stability for mobility, perhaps so should the anatomical curriculum sacrifice depth for breadth, including clinical application of anatomical knowledge.

One concern is that the core syllabus defines the *minimum* anatomical knowledge required of a new graduate. Yet, there is data to suggest that much of what is taught as part of basic sciences in the first couple of years of medical school is promptly forgotten (Custers, 2010). In a small study conducted a few years ago in our institution, we confirmed that 75% of a cohort of MD Year 3 students who sat for the same anatomy exam paper three months after finals failed the exam. They did much worse in Head and Neck, Neuroanatomy, Histology, Embryology and Cell Biology, than in the limbs, thorax or abdomen (Stabile, 2009). This is perhaps why as Morley (2003) stated, anatomical knowledge used to be imparted “just in case” it is needed in the future. So let us teach Everest, in the hopes that by the time they graduate they will at least remember Snowdon! Deciding what to leave out, while maintaining standards has become very difficult indeed.

Curricular change resulting in a reduced emphasis on anatomy teaching has led to concern that a new generation of doctors are leaving medical school with insufficient anatomical knowledge. In 2008, Fitzgerald surveyed newly qualified doctors at a UK medical school. Nearly half of respondents believed that they had received insufficient anatomy teaching, particularly in those who are planning to pursue a surgical career. In a review of several studies investigating the knowledge of anatomy of students at the eight Dutch medical schools, Bergmann and colleagues reported in 2008 that undergraduate students perceived deficiencies in their anatomical knowledge when they started clinical training regardless of their school's didactic approach. Moreover, test failure rates based on absolute standards set by different groups of experts indicated unsatisfactory levels of anatomical knowledge. Good test performance by students was related to total teaching time for anatomy, teaching in clinical context, and revisiting anatomy topics in the course of the curriculum. Importantly, these factors appeared to outweigh the effects of disciplinary integration or whether the curriculum was problem-based or traditional.

Another challenge facing institutions is to ensure that what is being taught in the anatomy class is not only relevant to clinical training but is vertically integrated with it across the whole academic programme of studies. I myself have had difficulty convincing my eminent colleagues in the Obstetrics and Gynaecology Department that a refresher on pelvic anatomy for year 4 students would be wise! Finally, we should remember that although anatomical knowledge is important, it is the application of this knowledge in terms of clinical skills that is paramount. So, unless we expect students to learn this, make sure we teach it and assess it carefully, we will be doing a dis-service to our patients, for whom ultimately the curriculum is designed.

4. ORGANIZING CONTENT

The MD degree curriculum has traditionally been seen as a progression from the basic sciences to the clinical sciences, with little if no attempt at integration. This is certainly the way most current anatomy tutors were taught 30 years ago! A major disadvantage of this approach is that since students do not see the relevance of what is being taught, most of it fades away very quickly indeed (Stabile, 2009).

Challenging students to begin to think like doctors from day 1 means that not only must the anatomical material be presented in an integrated manner, but students also need to be presented with clinical scenarios in which to understand the application of the anatomy that is being taught in the lecture hall or dissection room. One would expect students exposed to these types of learning opportunities to not only remain motivated but to also continue to see the relevance of basic sciences in clinical medicine.

Paradoxically, a more structured approach is required in developing an integrated curriculum than one based on the traditional distinction between anatomy, physiology, biochemistry, genetics, etc., in the basic sciences. This is because curriculum planners need to find logical ways of connecting concepts across several disciplines in order to convey key ideas.

It is in this context that Harden and Stamper (1999) have introduced the concept of a spiral curriculum whereby topics are revisited throughout the course, at increasing levels of difficulty. This allows students to relate new learning to what has been learned before and (hopefully) increase their competence level as they go through the programme.

Across the world, students are taught anatomy either through a systemic approach (musculoskeletal, cardiovascular, gastrointestinal, etc.) or a regional, also known as topographical approach (e.g., head and neck, thorax, abdomen, etc.). As illustrated by Pais and Moxham (2013), the regional approach takes on the broad aspects of the systemic approach in that the thorax includes the cardiovascular and respiratory systems, the abdomen contains the gastrointestinal and reproductive systems etc.

The difficulty in creating a systems-based approach lies in the interface between the body systems. For example, the important elements of the cardiovascular and respiratory systems lie in the thorax but so does the oesophagus. Should the oesophagus be covered as part of the gastrointestinal system? If so, how will we draw the students' attention to its important anterior relation of the left atrium? Similarly, the organization of the vascular and nervous supply of the abdominal organs is never as clear as when the abdomen is studied as a whole. A stab wound in the neck may affect neurovascular structures in the neck and/or the lung. Similarly, a stab wound in the chest may injure both thoracic and abdominal organs. How should we deal with teaching these?

Our institution has chosen a systemic and integrated approach while specifically catering for the limitations above by including a separate module called "Integrated Biomedical Sciences" This is where we make sure the interface is covered. Typical exam question in this module might be:

1. A 60 year old develops left shoulder tip pain. Disease in which organs may result in pain in this location? In each case describe the nerves involved in transmitting the pain signals from the organ to the skin.
2. A young father returning from a night shift is involved in a road traffic accident. Whilst his seat belt saves him from fatal head injury, mangled metal from the car door has pierced his chest on the right at the level of the 8^{th} rib close to the mid-axillary line. What organs and organ systems could be causing life threatening disorders and need to be assessed and why?
3. The same patient also fractured his pelvis at two sites as confirmed by pelvic X-ray. What are the soft tissue injuries which may accompany this and why could some of these again be life threatening?
4. The patient's blood pressure drops and he goes into shock. A central venous line is inserted in the right subclavian vein. What possible complications may occur due to the surrounding anatomy of the vein?

One advantage of the systemic approach to teaching gross anatomy is that it is readily integrated with teaching microscopic anatomy and embryology, at least in institutions that still teach these "old fashioned" subjects. A possible disadvantage is that the systemic approach may not be best suited for teaching involving dissection, although in our experience this can, and indeed must, be overcome by the tutor in the preparation of self-guided learning tools that continuously refer back to clinical context and a regional approach. The systemic approach has also been criticized as being unable to take into account precise locational parameters and relationships. Again, we believe that careful leadership by the tutor can overcome this potential limitation.

Another advantage of the systemic approach is that it lends itself more easily to integrating the physiological, pharmacological and pathological aspects of the structure/function dyad. However, if taken to its extreme, it may result in a "forced fit" where for example the physiology and pharmacology of neuromuscular junctions is squeezed into the musculoskeletal system to avoid a stand-alone anatomy module. Why do we seem to be afraid of this? What is wrong with simply teaching the upper and lower limbs together without reference to any other basic sciences? Does it have to be all or none, systemic or regional, or can a curriculum contain both approaches? We believe it can, and should.

McKeown et al. (2003) studied the impact of curricular changes following the publication of Tomorrow's Doctor on medical students' knowledge of surface anatomy by comparing examination results from the student intake of 1995 (traditional curriculum), with those from the student intakes of 1996-98 (new, 'systems-based' curriculum). Not surprisingly, the former were more likely to score higher than the latter in terms of knowledge of surface anatomy.

Hattie (2009) reported on 61 studies in two meta analyses involving nearly 8000 students and showed that the integrated (and by implication, the systemic approach) was not as effective as would have been expected and that teacher enthusiasm is a notable factor affecting success. Given that most of today's teachers of anatomy were themselves taught using a regional approach, with which we must surely feel comfortable, perhaps as Pais and Moxham (2013) have intimated, choosing the approach that works best for the teacher is of paramount importance.

5. SELECT THE INSTRUCTIONAL APPROACH

The above described curriculum models (which may indeed co-exist) raise another issue. Should we create a framework that puts the teacher or the student at the center of what we do? Should our curriculum be teaching oriented or learning oriented or perhaps both? Student centered learning focuses on what the student learns, as compared to student teaching which focuses on what we as tutors provide by way of teaching. If we believe that the former is paramount, then students should be made responsible for what they learn not only through lectures, but also by hands-on small group sessions. This is where students can interact with tutors over, for example, cases that illustrate anatomical principles, or prosections and imaging sessions to visualize structures in their 3D location. However, the reality is that across the world there has been a dramatic increase in the number of medical students, with most medical schools having large (200-300) student cohorts in every year. Our own institution has seen a 50% increase in student numbers in recent years. We would require a massive input of human resources (and therefore salaries) to expose all students to the same learning opportunities in small groups.

The concept of adaptive learning is an interesting one whereby students individualise the amount of time they spend in a particular module depending on their particular learning needs. So, with respect to an anatomy curriculum, a physiotherapy graduate who is studying medicine would spend more time on the head and neck, thorax and abdomen modules as the limbs would have been covered in far greater detail in their first degree. For this approach to be effective, students would need to be assessed before the end of each module to ensure there is enough time for top-up learning opportunities to be provided. Realistically, the chances that any institution can cater for the individual needs of particular students, is negligible.

It could also be argued that students with a first degree (graduates) have had far more experience with adult learning opportunities than school leavers who enter medical school at a much younger age (usually between 17 and 19). It could also be argued that students entering medical school after passing exams that require mainly rote learning and regurgitation of memorized material could be expected to handle self-directed learning opportunities rather differently than those who have survived a more holistic entrance examination process. Some medical schools in the UK have catered for these differences by running parallel courses for school leavers (5 years) and graduates (4 years, but with longer teaching time); these courses will then typically come together over the last two years of training which is usually run in common. Our institution runs a combined course where we have 18 to 20 year olds sitting next to 30 to 40 year olds. How do we cater for the pedagogic needs of both groups? Are we meeting the learning needs of both? Is it ever possible to do so? Maturity and previous world knowledge play an important role.

The other challenge that most medical schools face is the welcome presence of students from varied social, cultural, ethnic and economic backgrounds, not only from the same country, but often with different nationalities. In our limited experience, this is a bonus. Everybody benefits when the group discussing ethical dilemmas or the choice of investigation has students who have lived in a different country most of their life. However, these benefits bring with them significant challenges, such as language barriers, and mixed personal and academic backgrounds, all of which may impact the student's ability to learn from their mostly "uniform" tutors. We have experienced difficulties in teaching living anatomy or clinical skills in mixed sex classes with a few students from Gulf States feeling so uncomfortable about touching a member of the opposite sex, that they would rather skip class (and hence not learn).

As curricula have changed, so have the instructional methods used. As a medical student almost 40 years ago, during our two year-long basic sciences course, we were exposed to only lectures and practicals, the latter being weekly hands-on dissection sessions. There was no small group teaching, no self-directed learning, no case/problem or task based learning, no critical thinking sessions etc. Except for the dissection sessions, it was entirely passive learning and factual recall, a far cry indeed from the self-directed learning, problem solving and critical thinking sessions that my daughter is now experiencing at medical school.

As these "adult learning-based" educational strategies have slowly been introduced into the MD course, they have been avidly taken up by basic sciences tutors, transforming the teaching and more importantly, the learning of anatomy. The internet has also revolutionised student learning. Screen-based simulators, 3 D organ models, You Tube videos etc are widely used by medical students to access anatomical information, learn clinical skills and practical procedures. So much so, that the study guides that I now prepare for students start with a long string of hieroglyphics (https://)

A. Lectures

Given that meaningful learning occurs when the learner interprets, relates, and incorporates new information with existing knowledge and applies the new information to solve novel problems (Lujan and DiCarlo, 2005), it is hardly surprising that lectures are the least effective way for students to learn. Indeed, almost 50 years ago, Harden et al (1969) demonstrated that medical students learn less effectively from lectures than they do by independent study of specifically prepared learning resources. Nevertheless, lectures remain the mainstay of teaching in the majority of medical schools worldwide. Perhaps what is gradually changing is the role of lectures as a support for independent learning, rather than the reverse.

Avoiding lecturalgia, "a frequent cause of morbidity for both teachers and learners", (McLoughlin and Mandin, 2001), requires us to deliver lectures in the best possible way to help students learn. Clearly stated objectives (by the end of this session, students will be able to explain how….) are essential. Selecting key material, logical progression, using a variety of examples, and linking topics, all allow students to walk away feeling they have learned something from our lectures. Given that the more varied the contexts in which new information is presented, the greater the chances of remembering it are, we also advise students to read the material before coming to the lecture and follow this up with small group discussions to help with assimilation.

Structuring the timetable such that students sit and passively listen for no more than 45-60 minutes at a time (followed by a short break) seems to work best. Experience shows that students are most receptive in the first and last few minutes of that time period, hence that is the time to strike with the key messages. Ending a lecture with sample exam questions seems to work particularly well, as does asking students mid-lecture to tell you one thing they have learned so far. If no-one can indeed tell us anything, then either they are asleep, or we are far worse at imparting information than we think we are! Maintaining the students' attention for a whole hour can be challenging, but it is crucial. I sometimes think I should have taken drama lessons because learning to speak clearly, changing pitch and speed, using appropriate gestures, maintaining eye contact with the whole audience are essential to avoid the dreaded ABCDE…Annoy, Bore, Confuse, Distract, Exhaust (Acland).

It is possible, indeed beneficial, to engage students in some sort of activity during a lecture, even if there are 200+ students in the auditorium. Posing a question, asking them to discuss in a small buzz group and then bringing back their answers to the whole group is a well tried method. Indeed, students' recall of factual information is improved when they take part in an activity during a lecture (Cantillon, 2003).

Whether or not part of a formal review program, in our experience, personal reflection of our lecturing styles by viewing a video or asking for constructive feedback from a colleague, as well as student feedback is more valuable than one might otherwise think.

B. Small group learning

There is no doubt that teaching in small groups promotes student learning. However, small group teaching does not mean lecturing to small groups; student participation and interactivity are essential, as are also group work on a particular task and reflection on the results. I often begin such sessions by reminding students that what they get out of them depends on how much they put in. The size of the group is often dictated by yearly student intake and the availability of resources in the form of rooms, tutors etc. It is generally not under our control, but this matters less when one realises that the characteristics of the group are more important than the absolute size. (Twenty beginners are easier to handle than 10 mixed-ability students).

The advantages of small group work are many: deeper understanding of the material, development of inter-personal, teamwork and problem-solving skills, exposing students, maybe for the first time, to an adult approach to learning, thus laying the foundation for life-long learning. Nevertheless, these considerable advantages are negated by the experience of the tutor in handling these types of sessions. The less experienced the tutor, the more likely it is that these sessions become mini-lectures, and very expensive ones too! For a tutor's skills to evolve from the typical "lead from the front" tutorial approach to more of a facilitative role in which the learners take the lead in the discussion requires a paradigm shift in teacher training and learner expectations. When done well, the results are exceptional. Poor execution leaves both learners and tutors frustrated. Institutional investment in staff development is definitely worthwhile.

An experienced facilitator recognises the importance of setting ground rules, eliciting student expectations regarding their role, making sure that all members participate and interact with each other, keeping to time and keeping on track, providing feedback to the group and allowing sufficient time for reflection. "Tell me one thing you have learned today" is an excellent way of making sure that students engage in this reflective process. It also allows the tutor to identify students with difficulties that are oftentimes best handled in private (Walton, 1997).

In our institution, small group teaching is delivered in three environments: the dissection hall, the clinical examination room (living anatomy) and the tutorial room (critical thinking sessions). In the latter, students are provided with stylised clinical cases where all the clinical data including the diagnosis is provided. These short cases are then followed by a series of questions concerning the anatomical basis of the clinical and laboratory findings.

The following is a short example from the Muscles and Movement module.

Case 1: Fracture of the Clavicle

An 8 year old boy fell off his bicycle while riding down a steep incline and immediately complained of severe pain. All movements of his right arm are painful. He tries to avoid painful movement by holding the arm close to the body and by supporting the right elbow with the left hand. There is marked tenderness and swelling at the fracture site and the projecting ends of the fragments are easily visible and palpable. A fracture of the clavicle is diagnosed clinically. An X-Ray confirms the diagnosis and shows depression of the outer fragment.

Questions

Why is fracture of the clavicle one of the most common fractures in the body?

What factors keep the clavicle from dislocating at the sternoclavicular joint when an inward force is exerted on the shoulder?

Fractures of the clavicle are particularly common in the newborn. Can you provide an anatomical explanation for this? How might these fractures occur?

Which muscles are responsible for displacement of the fragments.

X Ray shows that the medial end of the lateral fragment is pointing posteriorly. What is the anatomical explanation for this finding?

Open clavicular fractures are rare. What is the anatomical explanation for this?

Name the muscle that protects important underlying structures against injuries from bony fragments. What are these important structures?

Injuries to the brachial plexus have been described as late complications of a clavicular fracture. What neurologic symptoms would you expect? In what area of distribution and why?

Can you think of any other complications of non -union of a clavicular fracture based on these important relations.

How is the fracture reduced?

Students are provided with the appropriate worksheets at least one week in advance to allow sufficient preparation time. One year, we experimented with online discussions (using the wiki function on Moodle) prior to the actual face-to-face encounter. As expected, the more committed the group was to experiental learning, the more successful the online interaction was.

We called these tutorials "Critical Thinking Sessions" because we wanted the main focus to be on interpretation, application and synthesis of anatomical information in a clinical context. Our year 1 students struggle with this as they are mostly school leavers, emerging from a mostly "spoon-fed" sixth form environment in which the main, if not sole, purpose is to pass exams with sufficiently high grades to allow automatic entry into medical school (as our institution has no numerus clausus or interview selection process).

One or two of these sessions per week facilitated by our most experienced tutors appears to be sufficient to transform the attitude of most of our students into an adult approach to learning by the time they start year 2.

We also encourage students to engage in small group sessions without the presence of a tutor, although we usually try to model what is expected out of these sessions at least once at the start of year 1. This is an adaptation of the concept of "donut rounds", wherein the role of the tutor, if indeed present, is solely that of providing the donuts! The idea is that students come prepared with 2 or 3 questions on a common topic, to which they know the answer. They then take it in turns to ask their questions, aiming to either accept or correct the answer of their colleagues. Several rounds of this occur, until all questions are exhausted. Here the learning is partly in the preparation (having studied the material), partly in learning how to ask good questions (a skill most of our students seem to struggle with), partly in hearing another student answer the question, and also to some extent from allowing the competitive nature of most medical students to emerge in a somewhat controlled manner.

Notwithstanding the benefits of small group teaching, lectures often complement the learning process. In our institution we strive to cover the main concepts, especially if they are difficult (e.g., the nerve supply of the pelvis, or the pterygopalatine fossa, just to give two examples), in an introductory lecture. An effective tutor can use a lecture to ask questions and will generally know whether the majority of students have understood the concepts being explained. In our experience, simple clinical cases illustrating clinical relevance can also be covered effectively in a lecture. However, in a well-run small group session, students do most of the talking, so the tutor can more easily spot the weaker students or those struggling with the concept. Each institution must decide what proportion of each type of teaching to use, primarily driven by resources including teaching and support staff, time available and funding.

Problem based learning, as distinct from case-based, in the type of Critical Thinking sessions described above, is a special form of small group learning, one where the facilitator may or may not be a content expert. Students are presented with a problem and the small (ideally ten or less) group of students critically explore the basic science and clinical mechanisms together with the relevant psycho-social and ethical issues. It is ideally suited for curricula that utilise an integrated approach to learning. Students bring their personal experiences to the table and the tutor provides a safe environment for interaction. The approach varies in different schools, but there is evidence that this approach results in understanding rather than memorisation, effective self directed learning, and teamwork (Norman and Schmidt, 2000).

C. Dissection

Dissecting cadavers helps gain an understanding of the three dimensional structure of the human body through self discovery and observations. It also helps to develop the spatial reasoning skills necessary to understand and interpret imaging data. Cadavers and prosections, whether plastinated or not, are only found in medical schools. It is only here that students can experience first-hand the "feel" of human tissue, the layering of structures and indeed, the three-dimensionality of relations. And yet, controversy over teaching methods has developed to the point that the importance of cadaveric dissection by students is being disputed. In a series of papers, Patel and Moxham surveyed 112 professional anatomists across the UK, showing that 70% preferred the use of human cadaveric dissection over other teaching methods.

The surveyed anatomists reported the following order-of-preference in terms of teaching methods:

Practical lessons using cadaveric dissection by students.

Practical lessons using prosection.

Tuition based upon living and radiological anatomy.

Electronic tuition using computer aided learning

Didactic teaching alone (e.g. lectures/class room-based tuition).

Use of models.

Heylings (2000) surveyed 28 anatomy departments in the UK and Ireland with a response rate of 75% to review the impact of Tomorrow's Doctors on anatomical teaching. At that time, twelve departments used systems-based curricula, five used problem-based curricula, and four used a traditional regional format. Dissection taught over the first 2 years was retained in 76% of the courses, frequently supplemented with demonstrations, with an average of 2 hours of practical work for every hour of lecture. Considerable variation in duration and staffing of anatomy teaching was reported but overall the average staff/student ratio was 1:20 in a dissection class.

In 2011, Kerby surveyed 580 Year 2 MD students across two UK medical schools with a 52% response rate, showing that not only did anatomists and students agree regarding the effectiveness of teaching methods, but that Dissection was overall most "fit for purpose" in meeting learning outcomes.

Azer and Eizenberg (2007) studied the perceptions of Year 1 and 2 students enrolled a problem-based learning curriculum with limited exposure to dissection, on its importance for understanding of anatomy. With a response rate of almost 90%, students, regardless of their gender or academic background, agreed that dissection deepened their understanding of anatomical structures, provided them with a three-dimensional perspective of structures and helped them recall what they learnt.

In our institution, students are assigned an anatomy project in the summer between Years 1 and 2. The project is an attempt to integrate active learning, cooperative learning, and problem solving into undergraduate medical education. Students are provided with list of topics or they may propose topics. They may choose to work singly or in small groups with a supervisor of their choice. The Project and its write-up are assessed by two internal and one external examiner. Kirresh and Stabile (2009) reported on 69 projects carried out by 138 students in 2 consecutive years. There was a statistically significant correlation between the marks obtained in the project and those in the final exam, in that students are more likely to perform better in that section of the exam that they undertook their project in. Moreover, there was a statistically significant correlation between student's mark in the project topic and the student's own mark in that same section of the exam. Apart from the fact that student projects contribute significantly to the department's prosected teaching material, students appear to benefit from the exercise. Many other factors that influence project mark and final exam mark were not controlled for in this descriptive study. Moreover, the fact that only 5% of final mark in the Anatomy Exam is awarded to project may have affected some students' dedication to the quality of the project.

A similar study by Jones and colleagues (2001) demonstrated that cadaver dissection by first year medical students provided a small performance advantage to Year 1 medical students' in the practical exam on material they had dissected.

So if some dissection is good, is more, better? Granger and Calleson (2007) compared the grades of Year 1 students dissecting half the body with those from the previous year when students performed all the dissections themselves. There was a statistically significant decrease in three of the four written test scores. However, students who dissected a particular structure did not score significantly better on practical questions concerning that structure than students who had not dissected it.

In a very small study published by Nnodim et al in 1996, two groups of medical students who had studied the gross anatomy of the lower limb by dissection and from prosections five years earlier, were re-assessed without warning. Numerical scores of both groups in the practical test were statistically similar, suggesting that (at least in this small study) the replacement of active dissection of cadaveric specimens by prosection-based methods did not appear to significantly impact anatomical recall.

More recently, Winkelmann (2007) reviewed the literature on the effect of cadaver dissection on cognitive learning outcomes. Although the review showed a slight advantage for traditional dissection over prosection, the student groups and course designs varied substantially across the 14 studies reviewed. The conclusion is that more sophisticated research designs with sufficient sample sizes and the use of validated assessment instruments are needed to be able to reach scientifically sound conclusions about the best way to teach gross anatomy.

The worldwide shortage of qualified anatomists limits the usefulness of cadavers in human anatomy teaching as this requires close supervision of students. Medical schools in geographically dispersed locations have developed novel solutions, including the "Prof in a Box". In this experiment, the anatomist sits in his office with a computer and video camera, connected to dissection rooms in multiple locations with iChat AV software and a secure server. The system allows the students and anatomists to interact via audio and video. Questions can be asked and answered and anatomical structures can be identified 'at a distance' in real-time. As this experiment has shown, it is indeed possible for a geographically dispersed faculty to provide instruction in the dissection labs at multiple medical schools. Perhaps this is the way forwards in this cash-strapped economy!

Just as dissection remains an essential technique to teach three-dimensional concepts, the cadaver dissection lab is an ideal place to introduce concepts of humanistic care. Lempp (2005) interviewed a handful of students in all years of medical training in the UK, concluding that the process of dissection leads students to address human mortality as well as their responsibility and privileged position in society. In other words, the process of dissection also offers learning in a social context.

A final word about plastinated prosected material, which is not only more robust, and but can also be stored at room tempera-ture. However, apart from the increased costs of the preparation technique, there are other disadvantages, as illustrated in the small study of Fruhstorfer et al (2011) who administered a questionnaire to 125 first-year medical students (response rate 68%). The majority of respondents (94%) rated plastinated prosections as a valuable resource for their anatomical learning citing the detailed view of relevant anatomy, appreciation of relations between structures, and visualization of anatomy in real life. However, learning on plastinated prosections was perceived to be compromised because of limitations in terms of tactile and emotional experience. This suggests that the learning experience based on plastinated prosections may be further enhanced by providing opportunity for the study of wet cadaveric material.

D. Peer assisted learning

Peer-assisted learning refers to any organised (as compared to ad hoc, informal or opportunistic) educational programme in which students are taught by their peers, who may be either in the same year or later. Topping (1996) reviewed the theoretical underpinnings as well as the research findings pertaining to Peer Assisted Learning. There is evidence that students exposed to peer tutoring perform better than those in control groups, irrespective of the age of the peer-tutors, and that, not unexpectedly, tutor training improves outcomes.

Nnodim (1997) reported on a controlled trial of reciprocal teaching in anatomy wherein students were divided into two groups, the first completing a dissection unit while the rest undertook private study. The first group then demonstrated the findings to the second group, and the roles were then reversed throughout the module. Student performance in the theoretical anatomy exam was significantly better in this group of students as compared to a control group who followed the whole module in the dissection room.

Our institution experimented with Peer Assisted Learning in the dissection hall a few years ago. The feedback from both tutors and students was uniformly positive. Tutors reported increased self-confidence, communication, organisational, and team-working skills. Most notably though, they reported benefitting themselves from the opportunity to revise anatomy before their own final exams. The student recipients felt more relaxed and less threatened in receiving feedback on their anatomical knowledge. As the person responsible for organising this pilot study, I came across resistance from a few of my faculty peers, as they raised a number of potential problems, which thankfully did not materialise. However, these are worthwhile reporting and they included choosing student tutors with inadequate knowledge, poor communication skills or inappropriate behaviour. In our experience, these potential problems can be overcome by having multiple tutors per session if at all possible. Our tutors did not undergo any formalised training other than a short induction by myself as coordinator.

There are a number of variations in this approach that could possibly be considered, such as tutors and students swapping roles, supplemental instruction for students who are experiencing difficulty, involving students in the development of resources such as prosections or illustrative videos, or even learning games.

Vasan et al. (2008) examined the value of team-based learning, an instructional strategy that combines independent out-of-class preparation with in-class discussion in small groups. Anatomy lectures were replaced with activities such as discussions after assigned readings and repeated self-assessments. Compared to traditional lecture-based teaching students performed better in the National Board of Medical Examiners final comprehensive subject exam.

E. Independent learning

As anatomy is mostly descriptive in nature, acquiring knowledge is hard work, as it lacks deductive principles to help learning and presumes continuous accumulation of data. On the other hand, it is one of the best ways to improve the student's memory, imagination, and observational skills.

Students can be great innovators: they see a gap and they create a solution to fill that gap. Study groups, donut rounds, peer support websites (Baker and Dillon, 1999), You Tube videos, you name it, they got it!

Before, but mostly after didactic teaching, students are required to “study” to master the material being presented in such a way that they can regurgitate it in bite size portions as required during the examination. How much of this independent learning students engage in depends partly on their innate memory, partly on the amount of detail they are required to learn and partly on how close they are to the examination date! We advise our students that 8 hours per day (including attendance at scheduled sessions) is the bare minimum, and that includes weekends and holidays.

We must not assume that students join the medical course with all the study skills necessary for independent learning. In our experience, many do not know how to assess their needs, manage their time, identify worthwhile learning resources, and most importantly, self-assess their progress.

The term self-directed learning, which is often used interchangeably with independent learning, implies that students are in control of their own learning: they decide what resources they need and how best to use them. They decide how, where and when to learn. Our role as tutors then becomes more facilitative, ie we guide their discovery of the concepts, illustrate the links between them and prepare illustrative resource materials. Done properly, this should not only help students master anatomical content, but also promote the development of independent learning skills that are a pre-requisite for life-long learning.

Independent learning can also be timetabled. For example, while one half of the group is learning how to examine the cranial nerves, the other half is looking up their origin and distribution. When the group comes together, students from each group are paired up and teach each other, under the watchful eye of their tutor. Students who are unable to answer the simplest questions in the dissection hall can be sent to the library to look them up and return when they have the answer!

The learning, and perhaps more importantly, the recall of anatomy, is based on the twin principles of observation and visualization. This is further enhanced by the interactive manipulation of 2D and 3D computer-based anatomical visualization tools (see below). Notwithstanding these tools and the ready availability of excellent anatomical textbooks, many students engage in superficial rote learning for exam purposes alone, without adequately understanding the overall picture. However, there is evidence that superficial and deep learning go hand in hand and students often utilise superficial learning first, before they are able to manipulate concepts leading to deeper learning. Smith & Mathias (2009) examined the approach to learning anatomy of 256 students in one UK medical school using a systems-based curriculum through prosections. In general, students reported that working on cadaveric specimens was an effective way of learning anatomy and their responses were significantly correlated with their approaches to learning. For example, students who reported that the most effective way of learning anatomy in the dissecting room was to manually feel for structures, those who frequently used their anatomy-radiology knowledge in clinical situations reflected a deep approach to learning anatomy. By contrast, a surface approach to learning anatomy was associated with elements, such as students finding anatomy learning daunting and not seeing the point to it.

Similar findings were reported by Panday and Zimitat (2007), who explored the key learning strategies of memorisation, understanding and visualisation in a study of 97 students in one Australian medical school. They concluded that the way students approach their learning of anatomy correlates positively with the quality of learning, thus confirming what most of us as teachers have long known i.e., successful learning of anatomy requires a balance between memorisation with understanding and visualisation.

Cognitive psychology provides insights into how and why context specificity affects the ability of students to retrieve anatomical information from memory. It would appear that the closer the context between what is being learned and the context in which the information is being used, the better the recall (Regehr and Norman, 1996). Curricula with strong horizontal integration especially when based on clinical cases, provide the opportunity for students to learn anatomical information in clinical contexts, albeit theoretical ones.

Moreover, deeper learning of key principles and clinically relevant anatomy requires students to assess themselves regularly. At a time when increasing numbers of atlases and textbooks are being published, those that stand out include study and review questions and answers as opportunities for self- assessment. In addition, the use of Donut Rounds as two-way sessions for learning to ask and answer questions is another example of a self-assessment tool that can be incorporated in the design of anatomy courses to enhance deeper learning.

6. HIGH QUALITY ANATOMY LEARNING RESOURCES

There is a common element in all the teaching approaches described above: the availability of high quality anatomy learning resources. Arguably, the institution’s efforts should be focused at least as much on creating these learning resources as it is on imparting detailed anatomical information, which many students can now access independently through the web. Each of the tools described below involves some form of hands-on learning. Since according to adult learning theory, adult learners are problem solvers that learn through doing, especially when what they are learning is of immediate use (Knowles, 1973), maximising exposure to experiential teaching modalities makes perfect sense.

A. Low tech simulation

Relatively inexpensive 3D organ models are widely used in some parts of Europe e.g., in Southern Italy where access to human cadavers is impossible. Our institution also uses simple plastic simulators to teach rectal, vaginal and breast examination, as well as vascular access, catheterisation etc. All these tools can be a useful adjunct to learning.

B. The Internet

The current generation of students are digital natives (Prensky, 2001), unlike their ageing tutors, having been immersed in technology from their early school years. They are highly adept at accessing relevant anatomical content and especially freely available resources on the internet. Specifically, Screen-based simulators, 3D organ models, You Tube videos, etc., are widely used by medical students to access anatomical information, learn clinical skills and experience practical procedures.

Limited research in the literature exists on the use of YouTube as a platform for anatomy education. Jaffar (2012) examined the online habits of 91 second-year medical students for whom video links were suggested throughout the academic year. The vast majority (98%) of the students used YouTube as an online information resource and 92% agreed/strongly agreed that the channel helped them learn anatomy. However, in an objective review, Azer (2012) screened more than 200 YouTube videos for their usefulness in learning surface anatomy. Less than a quarter were found to have relevant information to surface anatomy. Of these about a quarter provided useful information. Notably, no video clips covering surface anatomy of the head and neck, blood vessels and nerves of upper and lower limbs, chest and abdominal organs/structures were found. It would seem that at least at this time, YouTube is an inadequate source of information for learning surface anatomy. This will undoubtedly change.

Second Life™ is an Interactive 3-D virtual world on the Internet where “residents” socialize and connect using voice and text chat. Users create avatars i.e., representations of themselves, that travel throughout the virtual world organized into islands. Each island has a unique URL that is used to teleport to this location. Users may chat, explore, build, play games, conduct business, etc. An example of the use of second life as a supplemental teaching and learning tool in medical gross anatomy is the creation of a virtual anatomy lab (Richardson et al., 2011). Students collaborate in this virtual lab to build 3D models of conceptually difficult anatomical regions such as the pterygopalatine fossa. Another example is the cranial nerve skywalk, a 3D display of cranial nerves III, V, VII, and IX, with a virtual tutorial accompanied by slideshows of cranial nerve anatomy with an emphasis on specific parasympathetic pathways (http://slurl.com/secondlife/University%20of%20KY/186/46/235).

C. Imaging

Radiological images show anatomical structures in multiple planes and should therefore be effective for teaching anatomical spatial relationships, something that students often find difficult to master. Lufler (2010) reported on 179 Year 1 medical students who were provided with CT scans of cadavers, and given the opportunity to choose whether or not to use them during dissection. Students who used the CT scans were more likely to score greater than 90% on practical examination, final course grade, and on spatial anatomy examination questions than students who did not use the CT scans. However, there were no differences in performance between students who dissected the scanned cadavers and those who dissected a different cadaver altogether, indicating that it is the generic skill of interpreting images that provides added value in this approach to learning.

While the addition of imaging resources would logically be expected to improve the learning of anatomy, could it replace use of prosection-based studies? Griksaitis et al. (2012) randomised 108 Year 1 medical students to "cadaver-based" or "ultrasound-based" teaching of cardiac anatomy. Both groups were given a pre-test before randomization and a post-test immediately after teaching. Somewhat unexpectedly, both teaching modalities increased students' test scores with no significant difference between them, suggesting that both prosections and ultrasound are equally effective methods for teaching gross anatomy of the heart. Whether the same would be true of other regions of the human body remains to be seen.

Marker et al. (2010) used annotated, radiographic images organized to correspond to lecture and dissection topics to examine the perception of 120 students regarding this educational format in learning anatomy. They showed that the combination of electronic radiology resources available in lecture format and online can provide multiple opportunities for Year 1 students to learn and revisit anatomy.

D. Computer aided learning (CAL) software

Although dissection provides an unparalleled means of teaching gross anatomy, it constitutes a significant logistical and financial investment for educational institutions. In 2005, Inwood and Ahman reported the work of two undergraduate medical students who designed and produced 44 short dissection movies. Each movie precisely demonstrated the dissection and educational objectives for that class. Although the software was distributed to students free of charge, and was reported by students as being useful and easy to use, only a minority of them regularly used the software or had it installed on their laptop computers. Nevertheless, this study shows that CAL software can be employed to augment, enhance and improve anatomy instruction. In addition, it demonstrates that effective, high quality, instructional multimedia software can be tailored to an educational institution's requirements and produced by novice programmers at minimal cost.

This begs the question of whether computer aided learning is useful in anatomy. Several small studies have evaluated the effects of computer-generated 3-D anatomical models on learning. One such study is that of Nicholson et al. (2006) who reconstructed a fully interactive model of the middle and inner ear from a magnetic resonance imaging scan of a human cadaver ear. To test the model's educational usefulness, they conducted a randomised controlled study in 57 medical students, who completed a Web-based tutorial on ear anatomy that did/did not include the interactive model. There was a highly significant ($P<0.001$) difference in test scores of knowledge of 3-D relationships within the ear between the test and control groups.

Tam (2009) reviewed eight quantitative studies to evaluate the effects of computer-generated 3-D anatomical models in undergraduate medical student anatomy learning. Most of the studies were limited by small sample size (as above), as well as the lack of full interactivity of the models. Tam (2009) concluded that although in general, learners responded favourably in terms of educational satisfaction and enjoyment, there was insufficient evidence to show that these resources have a true place for replacing traditional methods in teaching anatomy.

E. Screen-based simulators (e.g., Vizua)

Some institutions have completely replaced cadaver-based anatomy classes, whether dissection or prosection-based, with highly sophisticated, and often prohibitively expensive, screen-based simulators. These create 3D screen-based models using CT, MRI and Ultrasound images which can then be manipulated, annotated and even digitally printed to create 3D models of anatomical structures. Free or low-cost alternatives are beginning to spring up, but none can replace the “feel” of human tissue. Nevertheless, there is anecdotal evidence that combining these tools with traditional cadaver-based learning may enhance the learning experience of students, particularly when used for self-learning and self-assessment.

In the future, Virtual Reality simulators, such as the Virtual Human Project being created at Oak Ridge National Laboratory (http://web.ornl.gov/sci/virtualhuman/) that utilise anatomical models, databases, visualization tools and supercomputing resources to create customized environments will eventually allow students to practice on virtual patients. One can only imagine how expensive this will be.

In our experience, most students, especially younger ones, enjoy “playing” with these tools. Whether the time spent “learning” is well spent, remains to be established.

F. Virtual learning environment (VLE)

The VLE is an integrated system of online tools designed to mimic the traditional learning environment (classroom, library, notice board, lab, etc.) to provide learning resources as well as administrative systems. Most institutions utilise either commercial (e.g., Blackboard) or open source systems (e.g., Moodle). Users access resources online and may also interact with each other and their tutors through tools such as wikis, synchronous chat rooms, asynchronous discussion boards or quizzes, among others. Some institutions have merged their VLE with plagiarising detection software such as Turnitin for students to submit assignments; some have merged in their library database search engines; others also their student information management systems.

Legitimate users access uploaded materials after the standard authentication protocol, thus minimising unauthorised use. However, there is nothing stopping an authorised user from disseminating downloaded material via the web. Perhaps it is not surprising that some tutors feel uncomfortable uploading soft copies of their lecture notes, or audio recordings of their lectures, often citing ownership and copyright rules. It is however possible to allow students to access but not download copyrighted material.

From an anatomy teaching point of view, the VLE can be an excellent repository of teaching materials, lectures notes, study guides, online tutorials, streamed video, worksheets, etc., as well as providing access to secondary learning resources. Although we encourage our students to share useful resources, our institution limits uploading resources to registered tutors, so students often resort to creating their own internal Google Drive or Facebook type of interactions.

When well managed, the VLE can also be used to track student performance in online interactions. Indeed, it is not the first time that we have identified students who have never accessed the VLE, in spite of receiving almost daily reminders that some particular learning resource is now available for their perusal!

G. Learning games

Learners, including medical students, across the world have changed. They have grown up surrounded by digital technology, such that keeping them motivated through “chalk and talk” is becoming increasingly difficult. Moreover, our generation of teachers learned from text supplemented with graphics, whereas today’s students prefer images, especially moving ones, to understand concepts. Prensky (2001) also points out the significant difference between the way our students learn by trial-and-error (e.g., clicking around on a website or game until they figure out what they are looking for or reach the maximum points in a game), and the more hesitant approach of some of their teachers who cautiously approach new software or hardware, almost afraid that they might somehow break it.

Digital game-based learning is one way to motivate learners while also moving them from linear thinking to the type of “hypertext learning” (Prensky, 2001) that allows them to think in terms of structures and patterns, a key element in the learning of anatomy. Moreover, digital games are enjoyable, interactive, have rules, goals and outcomes, leading to more creative, motivated students. This is the difference between tutors telling students about the anatomy of the inguinal region, and learning through dissection, interaction with other students, and why not, even games. Games that require active participation, decision making, learning from mistakes, use of multiple senses, are particularly suited to the learning of anatomy.

Game-based anatomy learning tools are widely available on the internet (http://zaidlearn.blogspot.com/2011/01/sizzling-collection-of-anatomy-games.html).

Some are very elaborate, others more simple, but most are fun and engaging resources. However, finding those aimed specifically at medical students can be difficult.

Anyanwu (2013) compared pre- and post-test scores of anatomical knowledge in a group of 95 medical students allowed to play with a specifically designed board game for 10 days as well as a group who did not. The post-test scores of the game group were significantly higher ($P < 0.05$) than those of their non-game counterparts. As part of their anatomy project, students at our institution have created a snakes and ladders type of board-game that utilises answering of questions based on the rolling of dice to review the anatomy of the upper limb. This is now in the process of digitised into an app for smart phones and other electronic devices.

In a study of over 800 Year 1 medical students in the US, Allen et al. (2008) investigated the effects of interactive instructional techniques in a web-based peripheral nervous system module. These included earning objects included Patient Case studies, review Games, Simulated Interactive Patients (SIP), Flashcards, and unit Quizzes. Student exam performance in anatomy was significantly better ($p < 0.05$) for those exposed to the interactive learning opportunities than for those who were not, albeit in a very small field.

Choudhury et al. (2009) studied the effectiveness of anatomy bingo and solving anatomical anagrams as well as five e Learning modules among optometry students at one UK university, showing a significant increase ($P \leq 0.01$) in the mean examination score in 2008-2009 after introduction of the interactive sessions and e-learning modules compared with scores in previous years.

SUMMARY AND CONCLUSION

Medical school has changed. Curricula have become more integrated, more systems based and the teaching of anatomy more clinically relevant. As the curriculum has changed, so have instructional methods. The so-called “traditional” anatomy course is heavily based on tutor-led lectures and student-led dissection. This didactic teaching approach has several advantages, not least the fact that all aspects of the human body can be covered systematically, albeit at different levels of depth, depending on whether the course is aimed at training physiotherapy, radiography, nursing, medical or dental students. This same approach seems to work well for surgical trainees, both generalists (in preparation for surgical exams) or at a subspecialty level through master classes. The weakness of this approach lies in the limited availability of human bodies to dissect. Given that anatomy is essentially a visual subject, the expansion of computer simulation techniques that visually engage students in 2D and spatial 3D constructions, is not unexpected. Some of these tools are expensive for institutions to purchase, but students (who are digital natives, as compared to their digitally immigrant teachers) can, and often do, access freely available digital media online via You Tube, etc.

Yet the purpose of teaching anatomy must surely lie in its clinical application. As teachers, our goal is to light the fire under our students, in such a way as to stimulate them to look for the answers to common clinical problems for which a knowledge of anatomy is essential. Thus, the use of small-group activities, be they problem-based or scenario (or case) based have either replaced the didactic approach or, as in most institutions, complemented it. These cases/scenarios are designed to enhance and reinforce (rather than introduce) anatomical knowledge. Through these sessions, students are pushed to expand their logical and critical thinking skills in applying anatomical principles to the explanation of clinical signs and the use of diagnostic and therapeutic procedures. This approach lends itself to self-study and can be successfully applied as from the first week of the course.

An early introduction to clinical problems adds context while also stimulating the student’s interest and hence improving recall. This increasing emphasis on learning within context gives this more “modern” anatomy course an advantage when applied to adult learners, which one would expect most of our students to be. Although adult learners prefer to do, rather than listen and watch, the extent to which an individual student engages with self-directed learning depends very much on their level of maturity, which in turn is a function of age, how they were taught and assessed in secondary/high school and whether they have another degree. Nonetheless, self-directed learning is the basis for the life-long acquisition of knowledge, and hence should be an integral part of the design of any anatomical course.

Over the years, medical curricula have “exploded” leading to difficulty in squeezing it all in. There is now much more basic and social science for students to learn, but no increase in the time available to learn it. Notwithstanding the efforts by the Anatomical Society to define the “core curriculum”, the difficulty lies in ensuring that what is being taught in the anatomy class is not only relevant to clinical training but is vertically integrated with it across the whole academic programme of studies. Deciding what to leave out, while maintaining standards has become very difficult indeed.

Across the world, students are taught anatomy either through a systemic or a regional approach, the latter becoming more popular in recent years. The difficulty in creating a systems-based approach lies in the interface between the body systems. The inclusion of cadaver dissection and/or examination of prosected material, remains at the core of anatomy learning, perhaps even more so when a systemic approach to teaching is used. This is because the learning, and perhaps more importantly, the recall of anatomy, is based on the twin principles of observation and visualization.

Deeper learning of key principles and clinically-relevant anatomy requires students to assess themselves regularly. At a time when increasing numbers of atlases and textbooks are being published, those that stand out include study and review questions and answers as opportunities for self- assessment. In addition, the use of Donut Rounds as two-way sessions for learning to ask and answer questions is another example of a self-assessment tool that can be incorporated in the design of anatomy courses to enhance deeper learning. A similar case can be made for Peerwise, an online peer-reviewed MCQ database (https://peerwise.cs.auckland.ac.nz).

The visible and palpable anatomy that forms the basis of clinical examination can only be learned through practice on normal subjects, usually fellow students and oneself. The design of an anatomy course must include opportunities for students to do this under supervision. Correlating these features with imaging studies further enhances deeper learning.

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