Original Research Article

Approaches of Anatomy Teaching for Seriously Resource-Deprived Countries: A Literature Review

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ABSTRACT

Background: Teaching anatomy is an important but expensive part of the medical curriculum, potentially more than many countries can afford. In the search for efficient methods, cost-effectiveness is of utmost importance for such countries. The aim of this contribution is to provide a review of the literature on anatomy teaching methods, evaluating these for feasibility in resource-deprived countries. **Methods:** A literature review was carried out to identify distinct approaches to anatomy teaching published in the period 2000–2014, 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. Based on their conceptual feasibility, dissection and technology enhanced 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 with regard to 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 virtual learning environment (for self-study), and at the end, using demonstration through prosected specimens and radiological imaging. This provides reasonable insights in anatomy through both dead and living human bodies and their virtual representations.

Keywords: Anatomy teaching approaches, anatomy teaching strategies, cost-effectiveness, resources-deprived countries

Background

Anatomical science has long been regarded a cornerstone in medical education.[1-4] Knowledge of the anatomy of the human body is important to understand how both structure and function are modified by disease[3,5] but also to perform a good physical examination.[4] The teaching of anatomy has, for many ages, 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 level of anatomy knowledge of medical students, many schools have explored and developed new and more efficient teaching approach. However, a factor that has been considered less frequently is the cost-effectiveness and feasibility under difficult circumstances. Teaching anatomy a dissecting room is one of the most expensive components of the undergraduate medical

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curriculum.[4] Many countries around the world 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 that the new strategy has been successful.[15-25] Failing education is rarely reported. Most reports do not compare approaches to anatomy teaching but describe a stand-alone educational method. Our aim was to identify educational strategies that fit the students' learning needs, specifically in low- and middle-income countries (LMIC), with the purpose to classify methods according to educational approach, resources, and feasibility.

The aim of this paper is to review the state of the art in anatomy teaching available in the scientific literature of the last 15 years, providing an overview or taxonomy of methods with their benefits and limitations with a focus on cost-effectiveness.

Methods

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

A review of original articles was performed in scientific journals on medical education that addressed the subject of anatomy education during a period of 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, and Francis. The starting year of 2000 was chosen as an estimated point in 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.

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

The articles were categorized as traditional (methods that commonly have been used in medical schools, these methods are mainly teacher-centered and nonintegrative) and innovative (strategies which emphasize an 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 needed for both students and teachers) and instructional effectiveness [Figure 1].

Instructional effectiveness was operationalized by analyzing the teaching strategies and relating to the nine principles that Mayer has proposed:[28]

1. Coherence principle: eliminate extraneous material
2. Signaling principle: highlight essential material
3. Contiguity principle: place printed words near corresponding graphics
4. Pretraining principle: provide pretraining in names and characteristics of key 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 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 these Mayer's principles of instructional design.

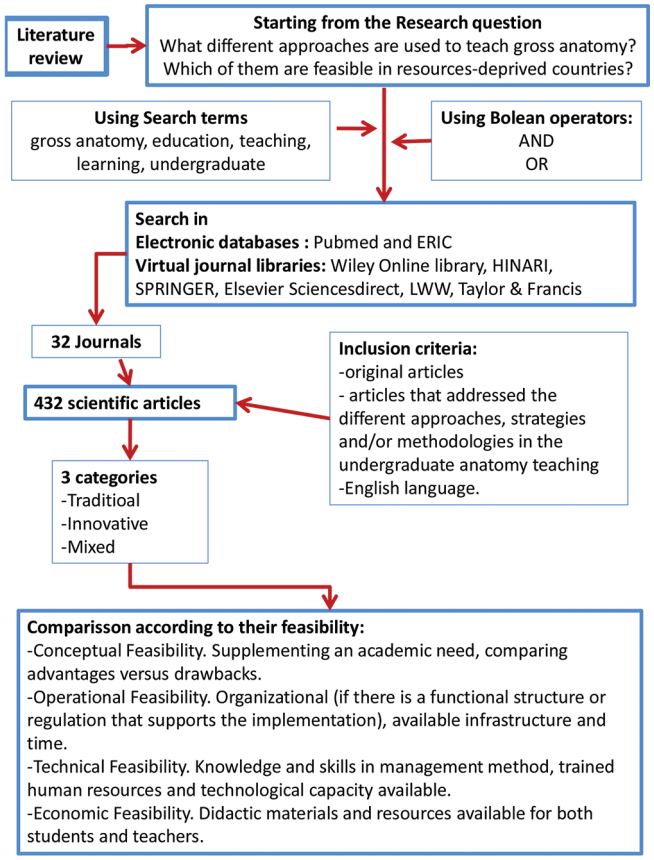

Figure 1: Literature search strategy

Results

From an initial yield of 607 articles about anatomy education, a total of 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 on conceptual, operational, technical, and economic feasibility [Table 1]. All teaching methods are described with their benefits and limitations in Table 2.

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 contents to a group. The event requires the presence of the participants in a specific time and location.[29]

Dissection

Dissection, one of the main anatomical learning tools in medical schools, has been used worldwide in teaching anatomy for >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]

Demonstration

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

Table 1: Anatomy teaching approaches

Approach	Strategies	Resources
Traditional[26]	Lectures/tutorials	Books, atlas
	Dissection	Cadavers
	Demonstration	Prosected cadavers
		Plastinated cadavers
		Plastic models
Innovative	Small group	
	PBL	
	Living body	
	Radiological imaging	X-ray, CT, USG, MRI
	Surgery observation	Operating room
	Physical examination	Peer examination. Simulated patients
	Body painting/drawing	Paint, paintbrush
	Technology-enhanced learning	Informatic resources: Software, CD ROM, Apps
	4th generation of e-learning	
	Computer-assisted learning	
	Telematics: 5th generation of e-learning: web-based learning	LMS Tools of Web 2.0
	Educational platforms	
	Social platforms	
	Miscellaneous	Diverse
	Unconventional	
	Comics trips/limerick	
	Yoga and pilates	
	Plasticine/clay modeling	

LMS=Learning management system, MRI=Magnetic resonance imaging, PBL=Problem-based learning, CT=Computed tomography

Prosected cadavers provide learners with predissected 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 dissection class. One study found knowledge retention of anatomy 5 years after training to be similar in 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 introduced in 1987. Using polymers such as resin, silicone, and polyester give 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]

Problem-based learning

A problem-based learning (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 his/her work. Students create and share learning objectives, including ones related to anatomy and obtain the required information through textbooks, the internet, assigned disciplinary resource staff, skill laboratories, anatomy museum, and audio–visual aids. Anatomy is incorporated in the majority of the problems and their accompanying learning activities; the proportions vary according to the problem or the system unit in question.[24,33]

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 very useful in studying some systems and/or organs such as muscles, bones, joints, peripheral nervous system (through the study of tendon reflexes), abdominal organs, and cardiorespiratory organs.[35,36]

Anatomy in the living body: Radiological imaging

Radiology education, such as radiographic, ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI), offers *in vivo* visualization of anatomy and physiology as well as insight into pathological processes.[12,37-41] Common methods to integrate radiology with anatomy instruction include concurrent radiology lectures, small group learning with and without formal instructors, and radiologic images of deidentified patients in the dissection laboratory.[42]

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 functional to teach anatomy. These procedures were also

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 retention of knowledge [82]. .Can reach large numbers of students (audience size is unlimited) in an efficient way.[29] Can be easily supported by expert-driven visual aids (clinical photos and computer animation) [29]. It s considered to be efficient for presenting information, providing explanations, and fostering enthusiasm for learning (Can motivate new learners if the lecturer can highlight interesting aspects and the importance of the subject in their professional training) [83] By adjusting already existing resources, lectures can be combined fairly easily and cost-effectively with other activities like e-learning. [83] Classic frontal teaching setups have the advantage of putting students into personal contact with teachers. [29]	Lectures require the presence of the participants 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 deeper learning activities. [83] Student listen passively to lectures and read their text but seldom involved in activities. [83,85] Lecture often fail to excite students by allowing them to discover the internal features and functions of the human body for themselves. [85] The 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 human body that leads to better understanding and learning of anatomy. [6,86] The practice of dissection in early stages of medical training has proven beneficial in the development of the 3 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 learnt. [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]	There is an emotional impact of dissection: anxiety and emotional disturbance have been described [52,91,92]. Dissection can be expensive, there are high economical costs of transporting, maintaining and disposing of cadavers.[4,25,36,59,63,64,65] There are fewer qualified gross anatomy faculty and fewer anatomy graduate students to teach anatomy trough dissection.[25,52,59,60] Dissection and self-instruction time is not adequate (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, 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 show concern about the smell associated with dissection. [30,36,52] Studying anatomy trough dissection of cadaver can loss 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. In some countries there are cultural and social barriers of dissection. [52,64,67,86,93] For some institution, cadavers may not be available. [59]
Demonstration	Prosection makes more time available for teaching, learning, and review [6,46,89] 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 inter-relations of anatomical structures including what lies beneath their examining fingers or stethoscope with minimal wear and tear [65,94]. Plastic model have longer shelf life; therefore, they are an inexpensive supplement. [65]	Plastic models lack of maintaining the natural variance or pathology of human body.[12,65] 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 plastinated model [46]. Prosection is a passive learning experience. [96] Learning with plastinated prosection was perceived to be compromised because of limitations in terms of tactile and emotional experience.[97] During plastination, there are several stages at which the process can be brought to a long time halt.[98]

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Anatomy teaching methods	Benefits	Limitations
	Plastic specimens can be modeled to perfection and possess a much longer shelf-life than cadavers. Plastic models do not account for biological variation and lack pathological authenticity which can lead to errors in physical examination in the clinical setting [12] Plastination gives differing mechanical properties that result in robust, dry, odorless and life-like specimens (realistic).[12,67] Plastinated material allows students to repeatedly study the specimens with minimal wear and tear.[12,66] Plastinated material is more robust and can be handling 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, also prevent exposure to the toxic substances (e.g. formaldehyde). [66]	A realistic estimate of a plastination laboratory is approximates U$ 50000 for equipment,[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 as a support to introduce anatomical basis of a region [24,33] Present a more integrated approach, in that normal structure and function of the human body are studied concurrently with the pathologies and clinical applications. [9,66,103] PBL aims to achieve both 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 learners developing autonomy in their own learning process (self -directed learning). [9,12,26,27,90] - In PBL session, students prepare group presentation to classmates, adding a dimension in using 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]	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] 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 to overcome their natural reticence about professional physical contact in an early phase of their medical training [35]- Students can develop understanding of the anatomy in context, and their sensitivity towards patients' need [12,36,105]. It s a method of studying living anatomy, it means, study the structure and function of organs.[25]	Difficulties may arise with students who come 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 which 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 facilitates reading/interpretation of radiological images for students which it s important to understand the consultation reports from radiologist in clinical practice, reducing the gaps between the learning environment and the practice environment [17,37,66,71,99,108] It promotes integration of clinically relevant content facilitates the understanding of 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. [72,103] 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. [104] The images can be manipulated to remove irrelevant tissues, allowing detailed study of particular organs.[46]	To obtain body-specific images, the cost of scanning bodies each year for students dissection is prohibitive.[102] 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] 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]

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Anatomy teaching methods	Benefits	Limitations
Observation of surgeries	Surgery allows students to apply what they have learnt from books, videos and models, to real-life patients [44] The mix of anatomy and surgery in interdisciplinary courses could improve a deep medical comprehension and improves clinical thinking.[72] Students that have access to surgical skills, have deeper insights into topographical anatomy. [73] 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 area being operated [44] are drawbacks. Integrating anatomy and surgery teaching requires more intensive supervision in a limit group size, but requires also more teaching staff.[72]
Body painting or drawing	It helps the learner to gain insight to the dimensions and positions of organs and surface projections of internal viscera [31,35] It helps to become familiar with important surface landmark anatomy, easy palpation and peer-examination.[22,31,35] Teaching clinically 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. Developing sensitivity towards patients need. [23] In body painting, structures such as the heart and pericardial cavity, and lungs and pleural cavities can be painted in 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]	Passivity of the model person and his/her loss of interaction with the 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 placing too much emphasis on art rather than on reliable organ positioning. [35] As this method is fun, fun can be distracting for students from the educational goals. [35]
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. In addition, another potential advantage is cost savings, because less qualified teachers can be employed to teach students. [29] Software of anatomy is odorless, allowed easy location of the relevant structures.[52] Self-rotating and multiple-view of the image gives dynamism and it s more attractive for the audience. It can be useful 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] where many structures are relatively small and inaccessible. [107]	Students do not have access to 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 an online resources have technical problems; students would have to work with outside providers to address any issues to find a solution. [38] The preparation of the material is rather expensive, time consuming and 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 effected 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]	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 as a problem the site navigation. [76]

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Anatomy teaching methods	Benefits	Limitations
	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] Online environment offers distinct advantages with regards to image quality, 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 as well as permitting flexibility in the material format.[73,107] Students can search easily different topic using user-generated key words.[107]	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. [76]. There is a requirement of an initial investment in time and computing resources. [93] Some anatomy web sites are lower quality sites from the didactic point of view. Thus a site can exist one day and disappear the next. [108] Depends on a good internet service, therefore failing servers can disable the student's learning process. Sometimes there are difficulties of connection. [108] The generation of computer-based representations of the whole body is very costly and requires institutional commitment.[109] All anatomy online programs lack inference capabilities, a requirement for inherent intelligence. [109] It can have a negative effect on the efficacy of the educational resource if the material is poorly organized.[73]
Social virtual platforms	The main attraction of the use of social networks is peer interaction, sharing experiences, opinions, concerns and information in a different classroom environment. [15,54,55,56,110] 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 to its users based on the previous viewing history. [15] YouTube is readily available, free resource, 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 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 favoured exam self-confidence, also provides formative assessment by providing feedback and peer-assessment.[54,110] Facebook may prepare medical students to go on 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 to use for today s students.[54] The majority of students has presence on social networking sites with predominance of Facebook.[110] Facebook is inclusive, easy to use and time-and cost-effective.[110]	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 requires extra time and effort by the faculty. [15] The anatomical information in YouTube videos may be misleading due to absence of content review. [56] To some, Facebook serves as more of a distraction than a learning tool.[54] Another negative impact reported by students is procrastination behaviour 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.[62] 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]

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Anatomy teaching methods	Benefits	Limitations
		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 the grouping, synergism, and antagonism of various muscles and it helps students understand cross-sectional anatomy.[21,39,58] Plasticines modeling is excellent vehicle for demonstration of the metacognitive process that enable self-regulation (a known predictor of academic success).[58] Plasticine modeling experience is nonthreatening, fun and exploits different learning styles. [58] Clay modeling has been used to improve student understanding of cross-sectional anatomy. [20] Clay modeling can be applied to any part of human body. [39] The use of 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]	Clay modeling is not an effective learning technique for long-term retention of knowledge about sectional anatomy.[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 and aponeuroses as well as 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 certain anatomical themes: muscle function, innervations, muscle attachment and location, muscle and bony landmark palpation, and clinical correlates [16]

CT: Computerized tomography, MRI: Magnetic resonance imaging, PET: Positron emission tomography, SPECT: Single photon emission computed tomography, USG: Ultrasonography, PBL: Problem-based learning, TEL-SDL: Technology-enhanced, self-directed learning

known as "theatre operations," which subsequently, due to the need to train surgeons, the theatres acquired educational functions and therefore became surgical amphitheaters[43,44] Nowadays, the operating theater is no longer an educational setting but, in contrast, a challenging place in which to learn; and especially suitable for medical residents.[45]

Anatomy in the living body: Body painting or drawing

Painting internal structures on the surface of the body can be effectively used in conjunction 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]

Technology-enhanced, self-directed learning in anatomy

Among the basic sciences, gross anatomy represents a unique opportunity for the incorporation of technology and electronic dissemination of information because of the visual nature of the course material.[38] There are teachers who have incorporated the 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]

Educational virtual platforms

In educational platforms, also called learning management system (LMS) or virtual learning environment (VLE), interactivity is an important 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]

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 YouTube's popularity should be considered an effective tool to enhance anatomy instruction if the videos are better scrutinized, diversified, and aimed toward course objectives.[15,56] but there is no consensus in the literature.[55]

Miscellaneous

Some have explored unconventional methods such as Comics trips/Limmerick,[20,57] Yoga and Pilates,[16] and Plasticine/clay modeling.[21,39,58] In such cases, "fun" is one feature they have in common, but they can also be useful for those students with preference for a kinesthetic learning style. However, these methods are limited to the study of a single system (muscle), as in the case of yoga and Pilates and clay modeling.[16,21]

For each of these 12 anatomical teaching methods, benefits and limitations are described, as well as Mayer's educational principles, and summarized in Table 3.

Discussion

For the selection of strategies, we must consider the type of content and skills to be developed, as we have seen, not all strategies are suitable for the teaching and learning of all content (conceptual, procedural, and attitudinal) and skills (cognitive, psychomotor, psychoaffective, and communication). Anatomy for its theoretical–practical nature needs strategies that develop both conceptual and procedural content, as well as cognitive and psychomotor skills.

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 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, for example, the curriculum, assessment, previous educational experience, and the influence of staff and fellow students. Not all faculty teaching anatomy appear to have had appropriate training in dissection techniques, radiological images reading, teaching methodology, or computer skills.[25,59,60] Anatomy teachers are usually medical doctors and senior medical students or recently graduated doctors, usually 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 to be optimal when teachers do not fully understand or do not enjoy what they teach. Motivation of faculty affects motivation of students.[61]

Dissection and prosection remain useful for understanding the three-dimensionality of the human body and the haptic perception, distinguishing the texture of the different tissues of the body.[4,5,25,30,46,62] However, its expenses are clear limitations, given the high costs of transportation, maintenance, and the disposing of cadavers.[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]

Table 3: Comparison of anatomical teaching methods on aspects of feasibility and proven instructional design principles (Mayer's principles)

Anatomical teaching methods	Operational feasibility			Technical feasibility	Economic feasibility	Attends to Mayer's principles of instruction (see methods section)								
	Organizational	Infrastructure	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/limmerick	(-) (-)	+++	(-)	(-) (-) (-)	(-)		+	+	+	+		+		
13. Plasticine/clay modeling	(-)	(-)	+	(-)	+		+		+	+		+	+	
14. Yoga/pilates	(-) (-) (-)	(-) (-)	+	(-) (-)(-)	(-) (-)		+				+		+	+

PBL=Problem-based learning, +++ Strongly feasible; ++ Very feasible; + Feasible; (-) Unfeasible; (-) (-) Very unfeasible; (-) (-) (-) Strongly unfeasible. Mayer's Principles: += applicable

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 operationally and technically a less feasible method in LMIC. PBL was not originally designed for the acquisition of basic science knowledge and is generally believed to be more suitable for clinical knowledge.[69]

The use of radiological imaging helps to give a more practical and applicable sense to the knowledge of gross anatomy, as radiology is rapidly expanding as a domain in medicine to visually represent the body in numerous ways.[42,70] However, it only meets 5 of 9 Mayer's principles, also its economic and technical feasible 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 it helps to increase the interest of a difficult topic such as the gross anatomy.[73,74] Online learning is reported to be as effective as traditional methods in the training of health professionals, yielding retention of skills and knowledge up to 25% more than traditional methods.[75] However, computer skills vary among learners, and there may be technical difficulties using the programs or platforms.[52,76] Despite these the 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 that are most found are the 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 the truly essential information (signaling) [Table 2].

The literature highlights successes of several approaches in the teaching of anatomy used so far. Therefore, an eclectic model, it means, a combination of complementary strategies could be the better way of teaching and the key to meet 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 anatomy course, traditional strategies such as lectures can be used to give a general orientation of the topic to study. Next, innovative strategies such as VLE for self-study session with the aid of a study guide, homework and academic chat to clarify doubts using. At the end, it can be practical classes on 2 phases, the first one, traditional with models and prosected specimens and the second one, innovative with use of radiological imaging and CAL (Computer Aided Learning), that way the anatomy is studied both in the dead (specimens/cadavers prosected) and *in vivo* (use of imaging) with an emphasis on self-directed learning. However, none of these methods are useful without a proper instructional design and without 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 feasibility of execution, technology-enhanced learning and educational platform methods seem most promising. However, it is important to remember that, despite the many benefits of technology in the

teaching of anatomy, "the most important thing in e-learning is not the technology, it's the teaching."[80] An aspect to consider is the pretraining principle in both students and teachers; these methods need training in how to use them (platform or software), how to design an online course and also professional staff who manage the educational platforms. In addition, it is important to have constant electrical power, a good and fast internet service, which fail in resources-deprived countries.[81] Not all these methods are economically and technically optimal, but it is expected that the economic and technical cost will decrease as the initial investments may serve many generation of students. In addition, compared to the cost of the maintenance that entails dissection, technology-enhanced learning and LMS are cheaper in the long term.

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