

Role of Living and Surface Anatomy in Current Trends of Medical Education

Mohammad Rehan Asad¹, Nazim Nasir²

¹Department of Basic Medical Sciences, College of Medicine, Majmaah University, Majmaah, Saudi Arabia

²Department of Basic Medical Sciences, College of Applied Medical Sciences, King Khalid University, Abha, Saudi Arabia

ABSTRACT

Teaching and learning of anatomy have greatly transformed in last two decades. Innovations in medical education, like integrated curricula and inclusion of PBL were considered to be responsible for the decline in anatomy learning. Allocated time for anatomy teaching has reduced in medical schools in last two decades across the world. Living and surface anatomy facilitates students in developing skills for future clinicians. Some educationist considered it to be main teaching tool for learning anatomy as a replacement of dissection based cadaveric anatomy. Innovations in medical technology and reduced allocated time paved the way for implementing teaching methodologies e.g., body painting, peer physical examination, medical imaging and virtual anatomy softwares in teaching and learning of living and surface anatomy. This article focuses on reviewing the historical background and current trends in teaching and learning of living and surface anatomy with special emphasis upon its pedagogical aspects also some views of medical educationists. It also compares pros and cons of various teaching methodologies used in learning of living and surface anatomy, emphasizing on challenges faced in its pedagogy. Finally, it concludes that living and surface anatomy should be considered as an integral part of the curriculum. Inclusion and implementation of teaching and learning strategies, such as body painting, peer physical examination, medical imaging and virtual anatomy softwares will enhance learning of living and surface anatomy in an integrated and relevant framework.

Key Words: Living and surface anatomy, medical education, body painting, peer physical examination, medical imaging

INTRODUCTION

Anatomy has been considered a key element of medical education for centuries and has survived current challenging pedagogic test of time.^{1,2,3} Gross anatomy with microscopic and developmental anatomy constitutes traditional anatomy curricula.⁴ The teaching hours of anatomy have been reduced in the United States from 1930s to 1980s, but the traditional teaching predominates and lacks integration and clinical correlation.^{5,6} There was a reduction of average teaching hours of the gross anatomy in medical schools, in the United States from 355 hours in 1955 to 149 hours in 2009.⁷ There was a dramatic change in anatomy curriculum since 1960, including discontinuation of cadaveric dissection and inclusion of prosection, radiological anatomy and simulation.⁸ From the time of the implementation of problem based curricula in the medical schools of Australia and New Zealand, an average of 171 teaching hours have been allocated for anatomy.⁹ The curricular reforms in anatomy were responsible for the clipping of all traditional disciplines of anatomy in United States medical schools i.e., gross anatomy, histology, embryology and neuroanatomy.¹⁰

Medical schools in Asia also adopted many curricular changes implemented in U.K., U.S.A., and Canada for last twenty years.¹² The changes such as reduction in allocated teaching hours, changing role of dissection in medical education and shifting of traditional teaching to an integrated teaching approach, were important factors that emphasize the role of innovative teaching and learning strategies in anatomy education of 21st century.^{13,14}

Living anatomy is explained as learning of anatomy by observing living human body. Most clinicians faces the body as living anatomy, whereas cadaveric anatomy is only encountered in the dissection room.^{15,16} In current pedagogical trends of anatomy, the function of living and surface anatomy has increased in medical curricula. In recent changing scenario of medical education, large number of medical schools introduced integrated curricula where basic sciences are learned with clinical correlations.⁴

An educationist promotes newer teaching modalities e.g., self-directed learning, problem-based learning, and computer-assisted learning mainly achieved by implementing living anatomy, surface anatomy and radiological imaging as teaching tools while a traditionalist (surgeons and anatomist) stressed on the importance of dissection of human cadavers.^{2,7,15,18,19} The reduced course hours and decreased time spent in dissection compelled many medical schools to upgrade the development of anatomical resources via new technological advancements eg. innovation in multimedia and by inculcating living anatomy sessions by peer examination, life models and imaging.^{11,14,17,20,21,22}

This article focuses on reviewing the historical background, current trends, and views of medical educationists and undergraduates towards teaching and learning of living and surface anatomy.

HISTORICAL BACKGROUND OF LIVING AND SURFACE ANATOMY

The history of anatomy teaching by using living human body can be traced up to 18th century.²³ Dr. William Hunter, an eminent anatomist of 18th century, during his lectures at Royal academy, used living models for demonstration of body movements. An eminent anatomist of late 19th century, Professor Mathis-Marie Duval, used living anatomy as a teaching tool for medical students.¹⁵ A manual titled "Living Anatomy" authored by Burns and Colenso, which was the collection of 12 male and 8 female illustrations, depicting muscles painted on the body, that were used in different actions and activities like kneeling, boxing, rowing, fencing, dancing and running²⁴ were also used for teaching. He emphasized the role of living anatomy as a supplement in training of anatomy obtained by dissection of cadavers in his book titled *Anatomy in living models*.²⁵ Living body is a first principle of learning anatomy as published in "*Living Anatomy: A photographic atlas of muscles in action and surface contours*".²⁶ Medical students were not getting chance to transfer anatomy that they had learned in the dissection room to the living body.²⁷ This could be considered as the first study, which correlates living anatomy with the rest of anatomy curriculum.²⁸

Physical examination was defined as a clinical application of surface anatomy.²⁹ Living anatomy and peer examination were correlated as learning methodology instead of live models and peer examination gave hands on practice to facilitate learning of surface anatomy.³⁰ Integration of clinical problems in teaching gross anatomy, including living anatomy and radiological anatomy, stimulates students learning of gross anatomy.³¹

CURRENT TRENDS IN THE PEDAGOGY OF LIVING AND SURFACE ANATOMY

Different teaching and learning methods such as computer multimedia, interactive lectures, small group learning, practical sessions and imaging have been discussed in understanding of living and surface anatomy.^{21,32} A survey conducted to explore current and future instructional methods for anatomy practicals in fifteen medical schools and sixty physical therapy schools in the United States reported that cadaver dissection was currently the most common teaching tool, but it predicts to decline in coming years, and more time will be dedicated for new technology based practices.³³ Living anatomy session augments learning of anatomy in students, facilitating in providing spatial orientation of body structures, learning of natural variations and introducing important clinical features of body surfaces.³⁴

Surface anatomy, imaging and therapeutic procedures were considered as three main modalities for learning living anatomy.^{13,21} Teaching methodologies used for surface anatomy included body painting, peer examination, living anatomy model, and full body digital X-Ray in combination with palpation of landmarks on peers and cadavers, supplemented with self-directed learning.^{28,35}

Body painting, an efficient and well accepted learning tool for living and surface anatomy provides conducive medium for introducing communication skills and promotes positive learning atmosphere.^{28,36,37} The first in incepting body painting as a learning method for teaching surface anatomy was used in 2002^{38,39}. Apart from efficient learning tool in anatomy education, body painting appeared to be relaxing and innovative way of learning which provided some relief to the students from text books.^{40,3,28,41,13} In body painting, the stimulation of visual stimuli with tactile trait of exercise facilitated easy recall of knowledge.³⁷

The surface anatomy provided enough opportunity to practice physical examination at very early stage in medical education, which prepared students for life-long clinical practice³. Peer physical examination was considered as one of the important and widely accepted teaching tool in conducting living and surface anatomy sessions.^{42,43,21,4,3,44}

Physical examination of “life models or fellow students” bodies during living anatomy session helped surpass their feeling of embarrassment improved their professional attitude towards patients, and also developed insight of what it is like to be patient^{45,46,21,44}. The peer physical examination helped students in developing mental picture of deep organs, facilitates practice of physical examination during clinical skills session and also expedite the performance of physical examination on patients in clinical surrounding.^{47,48,46}

Medical imaging technologies such as plain radiographs, CT scan, MRI, and ultrasound were considered as an efficient tool in learning of living anatomy.^{17,15,21,49,16} The most familiar imaging modality for studying living anatomy till now is a radiograph. The integration of radiological images in gross anatomy has reported to enhance the student’s proficiency to recognize radiological images, rectify their ability in identifying anatomical structures and facilitates long term knowledge retention.^{50,51}

The introduction of full body digital X-Ray images of cadavers at Department of Biological Sciences, Stellenbosch University during dissection session enhanced learning of surface anatomy.^{52,53} In 1994, Hannover Medical School in Germany introduced a program which consisted of radiology classes along with living anatomy session in basic sciences phase to introduce clinical application of anatomy.⁵⁴ Ultrasound demonstration session in Otago Medical School, New Zealand was started for third year students to teach living anatomy and the programme was found to be successful among the students.⁵⁵ Students find use of ultrasound as an innovative exercise, which stimulates learning of clinical anatomy accompanied with enrichment of their reasoning skills.^{56,49} The Brighton and Sussex Medical School in United Kingdom developed anatomy curriculum, which integrated living anatomy covering three dimensional imaging and surface anatomy as its domain along with cadaveric dissection.⁴⁵ The use of software that allowed students to project 3D reconstruction of structures on the surface of living body, when integrated with peer physical examination, body painting and other learning methods helped them to construct a precise representation of spatial relationship of body.^{57,49,59,13}

The College of Medicine, Majmaah University in Saudi Arabia, at the end of the basic phase, introduced imaging and surface anatomy longitudinal module of eighteen week duration with two contact hours per week. The students already possessed knowledge of body structures and anatomical landmarks.

VIEWS OF MEDICAL EDUCATIONIST AND MEDICAL UNDERGRADUATES TOWARDS TEACHING AND LEARNING OF LIVING AND SURFACE ANATOMY

Learning of surface anatomy gives intricate insight on static anatomy of cadavers by giving chance to students to visualize body parts in living human beings and also provides an opportunity to identify the variations between the individuals.^{59,13} The use of life models were graded superior to cadavers in learning of surface anatomy as it contributes students learning by offering anatomical contents, providing individual feedback in communication and examination skills and enhancing humanistic value of body³⁷. In 2003, a study was conducted in Queen University in United Kingdom to evaluate the impact of curricular changes on the knowledge of surface anatomy by comparing students of old traditional curriculum with students following new system based curriculum. The results of the study showed better performance of old traditional students compared with a new system based approach.⁶⁰ From the above study, it can’t be only argued that students of the traditional system are better than system based approach because this study was based on simple written examination testing, the first level “Knows” of Miller's pyramid, however, living and surface anatomy can be better tested as a skill which need to assess third level “Shows How” of Miller's pyramid.^{61,62,63}

In College of Medicine, King Saud University Saudi Arabia, the feedback from interns and medical students about anatomy curriculum identified that the gross anatomy duration was adequate, but coverage of clinical anatomy, imaging, living anatomy and surface anatomy were found to be inadequate. It was predicted that up to year 2020, expert physiotherapy anatomy instruction time will reach up to an average of 18%, and expert medical school anatomy instruction time spent on teaching of living and surface anatomy will cross on an average more than 1.5%.³⁴ General studies and survey carried out among medical and allied sciences colleges showed that the time allocated for surface anatomy, computer assisted teaching and imaging need to be increased.⁶⁵ The study was done by Patel and Moxham (2006) assessing attitudes of professional anatomist towards curricular changes in anatomy and its teaching and learning methodologies concluded prosection with living anatomy as second most preferred way of teaching, and it also revealed that more than ninety percent of anatomist engaged in the survey favors curricular changes, although dissection preferred to be most favorable teaching methodology.⁶⁶ The inclusion of “Living AnatoMe” program in Mt. Sinai School of Medicine in United States enhances medical student’s capability of comprehending anatomical knowledge along with providing a sense of physical awareness and wellbeing.⁶⁷

Learning of anatomy which included body painting, drawing, movement and surface anatomy, and she argued that multisensory hands on learning has been stimulated by all these methodologies.⁶⁸

The study regarding perception and attitude of first year medical students towards peer physical examination concluded that more than ninety percent students were comfortable for same gender with all body parts except for breast and inguinal region.^{69,70} Survey performed on the first year medical students at Guy's King's and St. Thomas Medical School London, United Kingdom, concluded that peer group models were main teaching methodology for learning surface anatomy although computer teaching, videos and lectures were complementing it.⁷¹ Introduction of web based tutorial of surface anatomy during teaching sessions improved knowledge of students.⁷³ The application of internet as learning resource has been increased in 21st century. Students are getting more dependent on the web for receiving information and seeking additional resources, so medical educators are required to modify their attitude towards the process of teaching basic sciences especially anatomy.¹⁴

The perception of touch is regarded as one of the primitive grown sensation in the human body and considered as most important for clinical practice.⁷⁴ The application of virtual tools by using haptic technology enhanced the capability to explore and perceive virtual anatomy.⁷⁵ They used a learning resource named anatomy workbench, which presented a 3 D dynamic model of finger anatomy, a visuo-haptic environment for interactive segmentation of visible human data and 3 D surface model of hand anatomy that can be palpated by pencil like device. The study conducted to collect feedback of the rectal palpation simulator "*The Haptic Cow*" from first year students of veterinary college, London received positive response about 3 D visualization and life-like feel of an internal anatomy without the need of using cadaver.⁷⁶

The acceptance of ultrasound in teaching and demonstration of living anatomy in medical students has been increased, due to lack of any significant side effects.^{77,78} Eight percent of medical students and seventy seven percent of dental students in a study conducted by Ivanusic et al. (2010) perceived that ultrasound imaging on a living human is effective in demonstrating anatomical structures.⁵⁰ The Ohio State University College of Medicine developed vertical ultrasound curriculum, where first two years mainly emphasize on understanding basic medical science by using ultrasound and in clinical years, the stress was laid on indications and image interpretation.⁷⁹ Studies showed that including integrated focused ultrasonography as the teaching supplement and a clinical support facilitates in training future physicians by acting as a bridge for integrating anatomy with clinical practice.^{80,79}

CHALLENGES

The hours allocated for the teaching of anatomy have been abruptly reduced in recent medical curricula.^{2,7,14} There is a need of careful planning to include students-directed anatomy objectives in the curriculum and its implementation. The difficulty in framing of anatomy curriculum is within the subject itself, due to "*competition for space and time*" between recently introduced but widely accepted perspectives e.g., surface and imaging anatomy, applied and clinical anatomy and anatomical variations that become an integral part of the anatomy teaching.⁸¹ The other significant challenge is about the methodology used in the pedagogy of living and surface anatomy. Different medical schools are adopting different ways or integrated approach of using more than one teaching methodology for surface and living anatomy; however, literature showed pros and cons of different teaching methodologies used for living anatomy and surface anatomy.^{82,21,14,44,13}

Studies showed that the effectiveness of body painting can be achieved, when it is conducted in conjunction with clinical skills.^{40,3,28,37,58}

Embarrassment, anxiety and feeling of discomfort before, during or after the session have been reported in students who participated in peer physical examination.^{83,84,43} Several studies showed that student's willingness and attitude towards peer physical examination were related to gender, age, religious background, and body image.^{83,15,85,87} A questionnaire based survey conducted by O'Neill and colleagues among medical students of mixed ethnic background in Manchester University concluded the religion as a factor for reluctance in performing peer physical examination especially female students from Islamic background.⁸⁹ The study done at Faculty of Health Science's, UAE regarding views of interns and senior medical students towards clinical skill lab concluded that the majority of female students were not comfortable in permitting peer physical examination of the body parts.⁸⁸

THE WAY FORWARD

Living and surface anatomy forms the bridge between clinical practice and gross anatomy.^{30,21,54} Challenges have been faced in teaching anatomy due to inadequately allocated time, but there is a need to look forward for proper integration of living and surface anatomy in medical curricula.^{89,7,45,90}

The living and surface anatomy should be considered an integral part of 'core' content of anatomy and need to be covered in practical sessions. AMEE guide no. 41 explained radiological anatomy and imaging as visual perspective of practical anatomy.⁴ The learning resources and activities need to be aligned properly with assessment as argued by Biggs theory of constructive alignment.⁹¹

There is a need to focus on the positive factors associated with learning of body painting such as kinesthetic nature, relatively inexpensive, associated motivation and enthusiasm among students.^{41,38} The body painting proves to be efficient if supplemented properly with traditional anatomy, clinical skills, drawing and labelling of the body parts.^{40,28,36,41}

Positive aspects associated with the physical examination such as skills and attitude development, integration of theory and practice, and acquiring precise knowledge of anatomical landmarks need to be addressed.^{92,44} Sensitive issues such as religious background, gender, examination of intimate body parts, which are affecting student's attitude towards learning methodology, can be resolved by complementing it through digital resources, providing standardized patients during a physical examination and with cadaveric marking.^{88,93} There is a need to introduce set written protocol, formal consent, and systematic training for involved faculty staff to address negative factors associated with peer physical examination.⁸⁵ The issue regarding the sensitivity of female students towards peer physical examination and body painting need to be studied more especially in the countries of Islamic background as there is a paucity of literature in this aspect. More studies are required to evaluate the efficiency of commonly used learning methods in living and surface anatomy and their impact on the students learning of surface anatomy, clinical skills like physical examination and procedures.⁴¹

Virtual Human dissectors can be used with projectors to superimpose anatomical images on the participants, facilitating peer examination. YouTube can be used as a point of knowledge for facilitating learning of surface anatomy was found to be insubstantial. The faculty members can contribute by adding their work on YouTube so that, so that it would be shared and disseminated adequately.⁹⁴

Dissection is still considered as an important tool in anatomy education, but various feedbacks and surveys showed increasing acceptance of living and surface anatomy in medical curricula. Teaching of living and surface anatomy has to move simply from cadaver based surface marking used in traditional curricula. It has to respond towards fast and rapidly changing medical curricula and surface anatomy need to be more evidence based and practically relevant. The increased acceptance of imaging and virtual anatomy among medical undergraduate students should be addressed and integrate properly with other teaching tools of living and surface anatomy.⁹⁵

Implementation and inclusion of above described innovative teaching strategies will facilitate learning of living and surface anatomy in an integrated, relevant, applied and contextual framework for medical students.

References

1. Lucic I, Gluncic V, Ivkic G, Hubensdorf M, Marusic A. 2003. Virtual dissection: A lesson from the 18th century. *Lancet* 362:2110–2113.
2. Turney BW. 2007. Anatomy in a modern medical curriculum. *Ann R Coll Surg Engl* 89:104–107.
3. Sughand K, Abrahams P, Khurana A. 2010. The anatomy of anatomy: A review for its modernization. *Anat Sci Educ* 3:83–93.
4. Louw G, Eizenberg N, Carmichael SW. 2009. The place of anatomy in medical education: AMEE Guide no 41. *Med Teach* 31:373–386.
5. McLaren DS. 1980. What to do about basic medical science. *Br Med J* 281:171–172.
6. Pawlina W. 2009. Basic sciences in medical education: why? How? When? Where? *Med Teach* 31:787-9.
7. Drake RL, McBride JM, Lachman N, Pawlina W. 2009. Medical education in the anatomical sciences: The winds of change continue to blow. *Anat Sci Educ* 2:253–259.
8. Leung KK, Lu KS, Huang TS, Hsieh BS. 2006. Anatomy instruction in medical schools: Connecting the past and the future. *Adv Health Sci Educ Theory Pract* 11:209–215.
9. Craig S, Tait N, Boers D, McAndrew D. 2010. Review of anatomy education in Australian and New Zealand medical schools. *ANZ J Surg* 80:212–216.

10. Hildebrandt S. 2010. Lessons to be learned from the history of anatomical teaching in the United States: the example of the University of Michigan. *Anat Sci Educ*. 3:202-12.
11. General Medical Council. 2003. *Tomorrow's Doctors: recommendations on undergraduate medical education*. 2nd Ed. London, UK: General Medical Council.
12. Gwee MCE, Samarasekera D, Chay-Hoon T. 2010. Role of Basic Sciences in 21st Century Medical Education: An Asian Perspective. *Medical Science Educator* 20: 299-306.
13. Bergman EM, Sieben JM, Smailbegovic I, de Bruin AB, Scherpbier AJ, van der Vleuten CP. 2012. Constructive, collaborative, contextual, and self-directed learning in surface anatomy education. *Anat Sci Educ* 6:114–124.
14. Ganguly PK. 2010. Teaching and learning of anatomy in the 21st century: Direction and the Strategies. *Open Med Educ J* 3:5–10.
15. McLachlan JC, Patten D. 2006. Anatomy teaching: Ghosts of the past, present and future. *Med Educ* 40:243–253.
16. Griksaitis MJ, Sawdon MA, Finn GM. 2012. Ultrasound and cadaveric prosections as methods for teaching cardiac anatomy: A comparative study. *Anat Sci Educ* 5:20–26.
17. McLachlan JC. 2004. New path for teaching anatomy: living anatomy and medical imaging vs. dissection. *Anat Rec* 281B:4–5.
18. Moxham BJ, Moxham SA. 2007. The relationships between attitudes, course aims and teaching methods for the teaching of gross anatomy in the medical curriculum. *Eur J Anat* 11:S19–S30.
19. Abu-Hijleh MF. 2010. The place of anatomy in medical education: Guide Supplement 41.1--Viewpoint. *Med Teach* 32:601–603.
20. Older J. 2004. Anatomy: A must for teaching the next generation. *J R Coll Surg Edinb Irel* 2:79–90.
21. Ganguly PK, Chan LK. 2008. Living anatomy in the 21st century: How far can we go? *South East Asian J Med Educ* 2:52–57.
22. Alexander CJ, Crescini WM, Juskewitch JE, Lachman N, Pawlina W. 2009. Assessing the integration of audience response system technology in teaching of anatomical sciences. *Anat Sci Educ* 2:160–166.
23. Strathern P. 2005. *A Brief History of Medicine from Hippocrates to Gene Therapy*. 1st Ed. New York: Carroll and Graf Publisher. 414p.
24. Burns CL, Colenso RJ. 1900. *Living Anatomy*. 1st Ed. London, UK: Longmans, Green and Co. 46 p.
25. Waterson D. 1931. *Anatomy in the Living Model: A Handbook for the Study of the Surface, Movements and Mechanics of the Human Body and for the Surface Projection of the Viscera, Etc*. 1st Ed. London, UK: Hodder & Stoughton, Ltd. 255 p.
26. Lockhart RD. 1928. *Living Anatomy: A Photographic Atlas of Muscles in Action and Surface Contours*. 1st Ed. London, UK: Faber & Faber Ltd. 71 p.
27. Barrows HS, Patek PR, Abrahamson S. 1968. Introduction of the living human body in freshman gross anatomy. *Br J Med Educ* 2:33–35.
28. Finn GM. 2010a. Twelve tips for running a successful body painting teaching session. *Med Teach* 32:887–890.
29. Bowsher D. 1976. What should be taught in anatomy? *Med Educ* 10:132–134.
30. Metcalf NF, Prentice ED, Metcalf WK, Stinson WW. 1982. Peer group models in examination instruction as an integral part of medical gross-anatomy. *J Med Educ*. 57:641–644.
31. Pabst R, Westermann J, Lippert H. 1986. Integration of clinical problems in teaching gross anatomy: Living anatomy, X-ray anatomy, patient presentations, and films depicting clinical problems. *Anat Rec* 215:92–94.
32. Spritzer VM, Whitlock DG. 1998. The visible human dataset: The anatomical platform for human simulation. *Anat Rec* 253B:49–57.
33. Gabard DL, Lowe DL, Chang JW. 2012. Current and future instructional methods and influencing factors in anatomy instruction in physical therapy and medical schools in the U.S. *J Allied Health* 41:53–62.
34. Collett T, Kirvell D, Nakorn A, McLachlan JC. 2009. The role of living models in the teaching of surface anatomy: some experiences from a UK Medical School. *Med Teach* 31:e90–e96.
35. Azer SA. 2013. The place of surface anatomy in medical literature and undergraduate anatomy text books. *Anat Sci Educ* (in press; doi: 10.1002/ase.1368).
36. Finn GM, McLachlan JC. 2010. A qualitative study on the student responses to body painting. *Anat Sci Educ* 3:33–38.
37. Nanjundaiah K, Chowdapurkar S. 2012. Body painting: A tool which can used to teach surface anatomy. *J Clin Diagn Res* 6:1405–1408.

38. Cody J. 1995. Painting anatomy on anatomy. *J Biocommun* 22:14–17.
39. Op Den Akker JW, Bohnen A, Oudegeest WJ, Hillen B. 2002. Giving color to a new curriculum: Bodypaint as a tool in medical education. *Clin Anat* 15:356–362.
40. McMenamain PG. 2008. Body painting as a tool in clinical anatomy teaching. *Anat Sci Educ* 1:139–144.
41. Azer SA. 2011. Learning surface anatomy: Which learning approach is effective in an integrated PBL curriculum? *Med Teach* 33:78–80.
42. McLachlan JC, Regan De Bere S. 2004. How we teach anatomy without cadavers. *Clin Teach* 1:49–52.
43. Wearn A, Vnuk A. 2005. Medical students and peer physical examination: two case studies of strategies to improve safety and increase acceptance. *Focus on health professional education: a multidisciplinary journal* 7: 88-98.
44. Chinnah TI, de Bere SR, Collett T. 2011. Students' views on the impact of peer physical examination and palpation as a pedagogic tool for teaching and learning living human anatomy. *Med Teach* 33:e27–e36.
45. Evans DJ, Watt DJ. 2005. Provision of anatomical teaching in a new British medical school: Getting the right mix. *Anat Rec* 284B:22–27.
46. Patten D. 2007. What lies beneath: The in living anatomy teaching. *Clin Teach* 4:10–14.
47. Boon JM, Meiring JH, Richards PA. 2002. Clinical anatomy as the basis for clinical examination: Development and evaluation of an Introduction to Clinical Examination in a problem-oriented medical curriculum. *Clin Anat* 15:45–50.
48. Outram S, Nair BR. 2008. Peer physical examination: Time to revisit? *Med J Aust* 189:274–276.
49. Ivanusic J, Cowie B, Barrington M. 2010. Undergraduate student perceptions of the use of ultrasonography in the study of "living anatomy". *Anat Sci Educ* 3:318–322.
50. Barros N, Rodrigues CJ, Rodrigues AJ Jr, Negri Germano MA, Cerri GG. 2001. The value of teaching sectional anatomy to improve CT scan interpretation. *Clin Anat* 14:36–41.
51. Miles KA. 2005. Diagnostic imaging in undergraduate medical education: An expanding role. *Clin Radiol* 60:742–745.
52. Kotzé SH, Driescher ND, Mole CG. 2013. The translucent cadaver: A follow-up study to gauge the efficacy of implementing changes suggested by students. *Anat Sci Educ* (in press; doi: 10.1002/ase.1365).
53. Kotzé SH, Mole CG, Greyling LM. 2012. The translucent cadaver: An evaluation of the use of full body digital X-ray images and drawings in surface anatomy education. *Anat Sci Educ* 5:287–294.(in press, doi: 10.1002/ase.127).
54. Teichgräber UK, Meyer JM, Berens von Rautenfeld D. 1996. Teaching applied anatomy to senior medical students with an emphasis on surgery and radiology. *Surg Radiol Anat* 18:141–142.
55. Stringer MD, Duncan LJ, Samalia L. 2012. Use of real time ultrasound to teach living anatomy: An alternative model for large classes. *N Z Med J* 125:37–45.
56. Tshibwabwa ET, Groves HM. 2005. Integration of ultrasound in the education programme in anatomy. *Med Educ* 39:1143–1172.
57. Durosaro O, Lachman N, Pawlina W. 2008. Use of knowledge-sharing web based portal in gross and microscopic anatomy. *Ann Acad Med Singapore* 37:998–1001.
58. Tam MD, Hart AR, Williams S, Heylings D, Leinster S. 2009. Is learning anatomy facilitated by computer-aided learning? A review of the literature. *Med Teach* 31:e393–e396.
59. Leonard R, Acland R, Agur A, Blevins C, Cahill D, Collins J, Dalley A, Dolph J, Hagedoorn J, Hoos P. 1996. A clinical anatomy curriculum for the medical student of the 21st century: Gross anatomy. *Clin Anat* 9:71–99.
60. McKeown PP, Heylings DJ, Stevenson M, McKelvey KJ, Nixon JR, McCluskey DR. 2003. The impact of curricular change on medical students' knowledge of anatomy. *Med Educ* 37:954–961.
61. Miller GE. 1990. The assessment of clinical skills/competence/performance. *Acad Med* 65:S63–S67.
62. Chakravarty M, Latif NA, Abu-Hijleh MF, Osman M, Dharap AS, Ganguly PK. 2005. Assessment of anatomy in a problem-based medical curriculum. *Clin Anat* 18:131–136.
63. Norcini J. 2008. An introduction to the assessment of skills and performance. *AMEE*.
64. Kaimkhani ZA, Ahmad M, Al-Fayez M, Zafar M, Javaid A. 2009. Does the existing traditional undergraduate anatomy curriculum satisfy the senior medical students? A retrospective evaluation. *Einstein* 7:341–346.
65. Chang JW, Lowe DL, Gabard DL. 2012. Current and future instructional methods and influencing factors in anatomy instruction in physical therapy and medical schools in the U.S. *J Allied Health* 41:53–62.
66. Patel KM, Moxham BJ. 2006. Attitudes of professional anatomists to curricular change. *Clin Anat* 19:132–141.

67. McCulloch C, Marango SP, Friedman ES, Laitman JT. 2010. Living AnatoME: Teaching and learning musculoskeletal anatomy through yoga and pilates. *Anat Sci Educ* 3:279–286.
68. Diaz C. 2011. For stimulating multidisciplinary first year students to learn anatomy for life via innovative, pro-active approaches to improve engagement and learning outcomes. Citations for Outstanding Contributions to Student Learning. James Cook University.
69. Barnette JJ, Kreiter CD, Schuldt SS. 2000. Student attitudes toward same-gender versus mixed-gender partnering in practicing physical examination skills. *Eval Health Prof* 23:361–371.
70. Rees CE, Bradley P, McLachlan JC. 2004. Exploring medical students' attitudes towards peer physical examination. *Med Teach* 26:86–88.
71. Aggarwal R, Brough H, Ellis H. 2006. Medical student participation in surface anatomy classes. *Clin Anat* 19:627–631.
72. Hallgren RC, Parkhurst PE, Monson CL, Crewe NM. 2002. An interactive, web-based tool for learning anatomic landmarks. *Acad Med* 77:263–265.
73. Barco T. 2010. Inclusion of surface anatomy in an integrated medical curriculum: A hands -on experience. *FASEB J* 24:S301.3.
74. Fager PJ. 2004. The use of haptics in medical application. *Int J Med Robot Comput Assist Surg* 1:36–42.
75. Dev P, Montgomery K, Senger S, Heinrichs WL, Srivastava S, Waldron K. 2002. Simulated medical learning environments on the Internet. *J Am Med Inform Assoc* 9:437–447.
76. Kinnison T, Forrest ND, Frean SP, Baillie S. 2009. Teaching bovine abdominal anatomy: Use of a haptic simulator. *Anat Sci Educ* 2:280–285.
77. Heilo A, Haansen AB, Holck P, Laerum F. 1997. Ultrasound 'electronic vivisection' in the teaching of human anatomy for medical students. *Eur J Ultrasound* 5:203–207.
78. Brown B, Adhikari S, Marx J, Lander L, Todd GL. 2012. Introduction of ultrasound into gross anatomy curriculum: Perceptions of medical students. *J Emerg Med* 43:1098–1102.
79. Bahner DP, Adkin's EJ, Hughes D, Barrie M, Boulger CT, Royall NA. 2013. Integarted medical ultrasound: development of an ultrasound vertical curriculum. *Crit Ultrasound J* 5:6.
80. Swamy M, Searle RF. 2012. Anatomy teaching with portable ultrasound to medical students. *BMC Med Educ* 12:99.
81. Grković I, Marinović Guić M, Kosta V, Poljicanin A, Carić A, Vilović K. 2009. Designing anatomy program in modern medical curriculum: Matter of balance. *Croat Med J* 50:49–54.
82. Chang EH, Power DV. 2000. Are medical students comfortable carrying out peer examinations on each other? *Acad Med* 75:384–389.
83. Rees CE, Bradley P, Collett T, McLachlan JC. 2005. "Over my dead body?": the influence of demographics on students' willingness to participate in peer physical examination. *Med Teach* 27:599–605.
84. McLachlan JC, White P, Donnelly L, Patten D. 2010. Student attitudes to peer physical examination: A qualitative study of changes in expressed willingness to participate. *Med Teach* 32:e101–e105.
85. Rees CE. 2007. The influence of gender on student willingness to engage in peer physical examination: The practical implications of feminist theory of body image. *Med Educ* 41:801–807.
86. Chen JY, Yip AL, Lam CL, Patil NG. 2011. Does medical student willingness to practise peer physical examination translate into action? *Med Teach* 33:e528–e540.
87. Rees CE, Wearn AM, Vnuk AK, Bradley PA. 2009. Don't want to show fellow students my naughty bits: Medical students' anxieties about peer examination of intimate body regions at six schools across UK, Australasia and Far-East Asia. *Med Teach* 10:921–927.
88. Koehler N, McMenamin C. 2012. Would you consent to being examined by a medical student? Western Australian general public survey. *Med Teach* 34:e518–e528.
89. Fasel JH. 1998. Teaching of gross anatomy to medical undergraduates: General practice as guidelines? A synopsis. *J Anat* 192:305–306.
90. Judson JP. 2012. The anatomy of anatomy. *Int eJ Sci Med Educ* 6:S48–S52.
91. Biggs J. 1996. Enhancing teaching through constructive alignment. *Higher Educ* 32:347–64.
92. Littlewood S, Ypinazar V, Margolis SA, Scherpbier A, Spencer J, Dornan T. 2005. Early practical experience and the social responsiveness of clinical education: Systematic review. *BMJ* 331:387–391.
93. Power DV, Centre BA. 2005. Examining the medical student body: Peer physical exams and genital, rectal, or breast exams. *Teach Learn Med* 17:337–243.
94. Azer SA. 2012. Can "YouTube" help students in learning surface anatomy? *Surg Radiol Anat* 34:465–468.
95. Hale SJ, Mirjalili SA, Stringer MD. 2010. Inconsistencies in surface anatomy: The need for an evidence-based reappraisal. *Clin Anat* 23:922–930.