

Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator

Tierney Kinnison, Neil David Forrest, Stephen Philip Freat, Sarah Baillie

Lifelong and Independent Veterinary Education, The Royal Veterinary College, Hawkshead
Lane, North Mymms, Hatfield, Hertfordshire, AL9 7TA, UK.

Tel +44 (0) 1707 666657

Fax +44 (0) 1707 666991

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

ABSTRACT

Traditional methods of teaching anatomy to undergraduate medical and veterinary students are being challenged and need to adapt to modern concerns and requirements. There is a move away from the use of cadavers to new technologies as a way of complementing the traditional approaches and addressing resource and ethical problems. Haptic (touch) technology, which allows the student to feel a 3D computer-generated virtual environment, provides a novel way to address some of these challenges. To evaluate the practicalities and usefulness of a haptic simulator, first year veterinary students at the Royal Veterinary College, University of London, were taught basic bovine abdominal anatomy using a rectal palpation simulator: 'The Haptic Cow'. Over two days, 186 students were taught in small groups and 184 provided feedback via a questionnaire. The results were positive; the majority of students considered that the simulator had been useful for appreciating both the feel and location of key internal anatomical structures, had helped with their understanding of bovine abdominal anatomy and 3D visualisation, and the tutorial had been enjoyable. The students were mostly in favour of the small group tutorial format, but some requested more time on the simulator. The findings indicate that the haptic simulator is an engaging way of teaching bovine abdominal anatomy to a large number of students in an efficient manner without using cadavers, thereby addressing some of the current challenges in anatomy teaching.

Key words: anatomy; simulator; haptic; virtual reality; veterinary; bovine

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

INTRODUCTION

Dissection classes have been central to anatomy teaching in both medical and veterinary professions for many years but are currently facing a number of challenges. The issues identified in relation to the use of cadavers in human anatomy (Aziz et al., 2002) are also mostly applicable to veterinary anatomy (Salazar, 2002). Dissection classes are time consuming and resource intensive and sourcing cadavers is increasingly problematic. There is also a high cost associated with acquiring, preserving and maintaining specimens. Furthermore, using cadavers raises ethical questions and can create psychological obstacles (Petersson et al., 2009): Indeed, moral and ethical issues were part of the rationale for the creation of an anatomy course without cadaver dissections at the Peninsular Medical School, UK (McLachlan et al., 2004). Concerns about the use of cadavers in veterinary education have also been raised by the public and the media and there is currently a move towards the 3Rs: reduce, replace and refine the use of animals in all contexts in veterinary education (Hart et al., 2005; Martinsen and Jukes, 2005). These pressures, together with those of time and resourcing, have meant that alternatives are being explored.

Over the last two decades, a variety of new methods and technologies have been developed to support and complement traditional anatomy teaching. Advances in preservation techniques, particularly methods of plastination, have helped to extend the life-span of specimens (Latorre et al., 2007) and have also alleviated some of the health and safety concerns associated with the use of formaldehyde as a preservative. Rather than using cadavers, another approach has been to introduce body painting on human actors or peers as a way of demonstrating the location and size of organs (Op Den Akker et al., 2002; McMenemy, 2008). Students also have access to an increasing selection of instructional material that incorporates multimedia and can include images derived from radiographs,

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

MRI, CT and ultrasound. For example, a CD-ROM entitled 'Virtual Canine Anatomy: The Head', has been developed containing dissection images and instructions, and was considered a useful tool during practical classes by students and staff (Linton et al., 2005). However, Theoret et al. (2007) suggested that a dissection video of the bovine abdominal cavity, although useful, was not a suitable replacement for gross anatomy classes. Computer graphics tools have been used to create 3D models that demonstrate anatomical spatial relationships, can be viewed from different angles and may help students to create 3D visualisations (Brenton et al., 2007). Examples include 'Yorick the 3D Skull' (Nieder et al., 2000) and, in veterinary medicine, the 'Visible Animal Project' (VAP) which shows 3D canine anatomy (Böttcher et al., 1999) and The Glass Horse (The Glass Horse, 2001).

Another advance in computer technology that could potentially contribute to anatomy teaching is in the field of 'haptics'; a term derived from the Greek word '*haptikos*' and meaning relating to the sense of touch. Haptic technology enables the computer user to touch as well as visualise 3D virtual objects (Srinivasan and Basdogan, 1997) whose properties can be varied e.g. soft or firm, and with a smooth, rough or sticky surface. The technology is finding increasing applications in human and veterinary clinical training and is particularly valuable for simulating examinations that rely partly or wholly on the sense of touch. Examples of virtual reality (VR) haptic simulators include the Virtual Haptic Back for teaching osteopathic examination (Williams et al., 2004), a prostate simulation (Burdea et al., 1999) and, in veterinary medicine, the Haptic Cow for teaching palpation of the reproductive tract per rectum (Baillie et al., 2005a), a feline abdominal palpation simulator (Parkes et al., 2009) and SimPooch for teaching canine acupuncture (SimPooch, 2008). The initial focus has been on designing simulators to teach clinical skills. However, to address a

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

specific need in anatomy teaching at the Royal Veterinary College (RVC), University of London, UK, we explored the potential of the Haptic Cow simulator in anatomy.

At the RVC, first year students learn the anatomy of the common domestic species in lectures complemented by dissection practicals. Sheep cadavers are used to teach ruminant anatomy, but cattle are not dissected through reasons of cost, specimen availability and disease control restrictions associated with bovine tissue. It is also not sustainable or acceptable on welfare grounds to allow the large number of students in the preclinical course to perform rectal palpation on live cows. Rectal examination of cattle is however a required and essential practical skill of veterinarians for fertility manipulation, pregnancy diagnosis and gastrointestinal system examination. Knowledge of the 3D topography and structure of abdominal organs has to be developed through the student's or veterinarian's sense of touch.

The purpose of our study was to determine whether it was feasible and practical to use the Haptic Cow to teach bovine abdominal anatomy and to gather feedback from students.

METHODS

Anatomy Tutorial using the Haptic Cow

The Haptic Cow simulator consists of a force-feedback haptic device (PHANToM Premium, SensAble Technologies, Woburn, MA, USA) positioned inside a fibreglass model of the rear-half of a cow. The student places his / her middle finger in a thimble attachment at the end of the PHANToM's mechanical arm and palpates virtual models of the reproductive tract and surrounding structures. The Haptic Cow has been embedded into several veterinary curricula

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

in the UK (e.g. Baillie et al., 2005a) and has been validated for providing transferable skills for finding and identifying the uterus in a real cow (Baillie et al., 2005b). At the RVC, the simulator is currently used in third year (of a five year course) as part of the bovine reproduction module and in final year during a role-play exercise. The current study represents the first use in an anatomy course.

Discussions with anatomists led to a list of structures that should be included in a bovine abdominal anatomy simulator: the pelvic landmarks, rumen, left kidney and aorta (with a pulse). The simulator was aimed at first year students and taught abdominal anatomy 'as seen from the tail' (caudo-cranially) – the way farm animal veterinarians 'view' the cow when performing rectal palpation. The customised version of the Haptic Cow was produced and a teaching protocol developed for the tutorial. The aim was for students to appreciate the topographical anatomy and to become aware of each structure's distinctive feel and 3D position.

The simulator tutorial was included as part of a two day anatomy practical in which students also dissected sheep cadavers. The tutorial was delivered to small groups of five to seven students (Figure 1) and lasted approximately 20 minutes.



Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

Figure 1. The student is able to feel the 3D virtual structures inside the fibreglass model of the cow. The computer tracks the hand movements which helps the tutor direct the student and give feedback.

To accommodate the large class size, two Haptic Cow simulators were running at the same time with an instructor for each. The instructors explained the aims of the tutorial to the group, directed each individual while using the simulator, and concluded by summing up the session.

Evaluation

A questionnaire was designed to gather feedback from students and was administered online immediately after the tutorial using SurveyMonkey (SurveyMonkey, 1999). Students responded to statements relating to the effect of the simulator on their ability to find and identify abdominal structures on a five-point Likert scale (from Strongly Disagree to Strongly Agree). Further statements determined opinions about the tutorial format and the use of a simulator in anatomy. In a final section, students were asked to list other potential applications for haptic simulators in anatomy and to suggest improvements to the tutorial. Students could also enter general comments about the tutorial at the end of the questionnaire. Quantitative analysis was carried out with the Statistical Package for the Social Sciences (SPSS) Version 17 while NVivo 7 was used to identify themes in the qualitative data.

Completion of the questionnaire was voluntary and students were asked to give consent for their data to be analysed and used anonymously. The project received ethics approval from

Kinnison, T., Forrest, N.D., Frean, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

the RVC Ethics Committee, which has standard procedures and guidelines for educational research involving students.

Kinnison, T., Forrest, N.D., Frean, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

RESULTS

The Haptic Cow was included in the large animal anatomy practical and 186 students (of a possible 189 enrolled on the course) were taught over the two day period. The post-tutorial questionnaire was completed by 184 students (98.9%).

Quantitative Evaluation

Students' responses to statements about the simulator tutorial are shown in Table 1. The majority either agreed or strongly agreed that as a result of the Haptic Cow training they would know how to find key abdominal structures palpable per rectum, specifically the pubis, left kidney and aortic pulse, and identify the rumen by feel (Table 1 Part A). Students recognised the value of the simulator in contributing to their understanding of anatomy, 3D visualisation of the bovine abdomen, and particularly its usefulness as an aid to learning gross anatomy (Table 1 Part B). With regard to the tutorial structure, the statement responses had a higher variance but the majority supported the small group format and considered that the length of the tutorial was satisfactory). Most students strongly agreed that the session was enjoyable (Table 1 Part C).

Kinnison, T., Forrest, N.D., Frean, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

Table 1

Likert scale responses (n = 184) to questionnaire statements.

SD = Strongly Disagree, D = Disagree, N = Neither Agree nor Disagree, A = Agree, SA = Strongly Agree.

Part A. Knowledge gained by using the Haptic Cow

Statement	Response (frequency)				
	SD	D	N	A	SA
As a result of the Haptic Cow Training:					
If I was to rectal a cow, I would now know how to find the pubis (pelvic brim)	2	5	9	113	55
If I was to rectal a cow, I would now know where the left kidney is	1	7	14	133	29
If I was to rectal a cow, I would now know how to feel for the aortic pulse	1	2	4	108	69
If I was to rectal a cow, I would now know what the rumen feels like when palpated per rectum	1	12	19	118	34

Part B. Value of the simulator in anatomy teaching

Statement	Response (frequency)				
	SD	D	N	A	SA
The simulator has helped with my understanding of bovine abdominal anatomy	1	3	9	107	64
I found the simulator useful for appreciating the feel (e.g. softness / firmness) of the different structures	4	4	19	100	57
I found the simulator useful for appreciating the location (e.g. left / right, dorsal / ventral) of the different structures	1	5	8	109	61
As a result of the Haptic Cow Training, I can now visualise bovine abdominal anatomy in 3D (as seen from behind)	1	3	9	146	25
I think haptic simulators are a useful aid to learning gross anatomy	2	4	3	85	90

Part C. Tutorial format

Statement	Response (frequency)				
	SD	D	N	A	SA
I was concerned about learning anatomy via a computer simulator	19	59	73	32	1
I would have preferred if the tutorial had been one-to-one (i.e. not a small group)	23	81	53	25	2
The length of the tutorial was satisfactory	3	44	36	88	13
I enjoyed the tutorial	0	1	3	83	97

Kinnison, T., Forrest, N.D., Frea, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

--	--	--	--	--	--

Qualitative Evaluation

The majority of students (89.2%) entered comments in response to one or more of the questions in the final section. When asked to list other applications of haptic simulators (134 entries) most suggestions related to the disciplines of reproduction and obstetrics across all major species. Improvements to the tutorial (111 entries) were mostly classified under two main categories: tutorial time - making it longer / having another go (45.0%) and expanding the simulation to include models of additional structures (30.6%). In the general comments section (88 entries), three main categories emerged: positive (75%), negative (8%) and improvements (17%). Within the positive comments most referred to the usefulness of the simulator tutorial, for example appreciating 3D topographical anatomy:

“Definitely helped me understand and gave me a 3d view!”

“The most useful aspect was the spatial awareness the simulator gave you of where the organs were within the abdomen and in relation to each other”

Other comments included:

“It was a really useful session and good to experience a different use of media to provide a more rounded approach to our learning.”

“I think it is very clever, a good idea, and is useful as no animals are bothered.”

In relation to the dynamic aspect of a 3D haptic-enabled simulation:

“The pulse feature [*aortic pulse*] was also really impressive”

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

Additionally, students expressed their enjoyment of the experience:

“I really enjoyed the haptic cow and think it was definitely worth doing”

“This tutorial was a fantastic learning experience, really very useful.”

In the comments classified as negative or improvements, students raised the issue of the haptic device providing only a single point of interaction and expressed a preference for being able to use the whole hand. Also some students reported difficulty in appreciating the feel of some structures whereas other comments (positive) reported: “[it] had a surprisingly "real" feeling.”

DISCUSSION

In modern medical and veterinary curricula anatomy teaching is facing a number of well recognised challenges. For example, practical dissection classes are increasingly difficult to sustain because of limitations on the availability of cadavers and their cost, time constraints and ethical concerns (Aziz et al., 2002; Salazar, 2002). At the RVC, these problems have come to constrain the teaching of bovine abdominal anatomy. Students no longer dissect bovine cadavers or perform rectal palpation of the live animal at this stage in the course. As an alternative we introduced a virtual reality simulator, the Haptic Cow, into first year anatomy practicals to explore the potential of this technology in anatomy teaching.

Over a two day period we were able to teach a large number of students (186) bovine abdominal anatomy ‘as seen from the tail’ using the simulator. The feedback indicated that most students found the tutorial enjoyable and considered that using the simulator had beneficial effects on their knowledge and understanding of bovine abdominal anatomy and

Kinnison, T., Forrest, N.D., Freaan, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

ability to find and identify key structures and landmarks. This is important not only for students' appreciation of topographical anatomy but also as a prerequisite for performing rectal palpation on real cows. Interestingly, most students were also supportive of the small group format and relatively short session although some expressed a desire for more time and opportunities to use the simulator. Teaching in a small group was more efficient than one-to-one and also enabled students to learn while watching and listening to others. The format was chosen primarily for logistical reasons, specifically the requirement to teach the whole class within the existing timetable allocation for a dissection class. As this proved practical, achievable and acceptable to students, a similar approach will be taken in the future.

The tutorial was undoubtedly popular with students and their feedback suggested that there were beneficial effects on learning. However, this cannot be guaranteed without some form of independent objective measurement. Providing evidence to support the efficacy of any teaching intervention is important but gathering such evidence is not necessarily a simple undertaking, particularly in the context of simulator-based training. For example, for high-fidelity simulators used in medical training, only a few studies have been able to demonstrate that learning has taken place (Issenberg et al., 2005). When used in the clinical part of the course, the Haptic Cow has been shown to equip students with skills that helped them find the uterus when subsequently examining live cows (Baillie et al., 2005b).

However, further research will be needed to confirm and quantify the benefits in relation to the learning objectives of the anatomy course. It would also be interesting to investigate the contribution of the simulator to students' spatial skill development, one of the aims of anatomy teaching. The feedback in the current study indicated that students recognised the potential value in this area and it seems reasonable to expect that physically exploring a 3D

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

virtual environment with haptic (touch) feedback would help students build up a mental model of the anatomical layout. However, the beneficial effects of 3D graphics have been questioned as studies have indicated that key views (with slight rotation for the third dimension) are most important for gathering spatial information (Garg et al., 2002; Levinson et al., 2007) and multiple views may actually disadvantage those learners with poor spatial ability. Therefore, future studies are planned to investigate the effects of learning in a 3D haptic simulation on the development of spatial skills and to explore its potential to train those with poorer abilities and support different learning styles.

In the current study, a tutorial with the Haptic Cow was introduced because of the specific problems of trying to teach bovine abdominal anatomy when access to cadavers and live animals was not possible. As well as addressing these issues, using a simulator has clear benefits for animal welfare. Most anatomy courses are facing similar challenges and haptic simulators could be used in other contexts and species, including human. Our students' suggestions focused on obstetrics and reproduction although this was probably influenced by their impending work placement, i.e., lambing on a sheep farm. However, before exploring further applications of haptics, there are certain hardware and software issues that need to be considered. The PHANTOM device used for the Haptic Cow is costly and provides only a single point of contact, when using the whole hand would be preferred. Creating virtual models has also proved challenging, both in achieving realistic representations (Burdea et al., 1999) and in the time required (Baillie et al., 2003). Fortunately, devices are emerging that support different means of interaction and cheaper options are becoming available, driven largely by the computer-gaming industry. There are also techniques that are speeding up the simulation development cycle. A feline abdominal palpation simulator (Parkes et al., 2009) benefited from a rapid prototyping haptic

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

environment (Forrest and Wall, 2006) and the virtual models can also be built using CT and MRI data.

The future of anatomy teaching will inevitably continue to change and haptic simulators have potential to complement existing methods, to address some of the problems and issues, and to bring a new dimension to the student learning experience. We will continue to use the Haptic Cow to teach bovine abdominal anatomy and plan to explore further opportunities for this novel and exciting technology in anatomy courses.

Kinnison, T., Forrest, N.D., Frean, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

ACKNOWLEDGEMENTS

Dr Sarah Baillie is the developer of the Haptic Cow which has been distributed to several veterinary schools in the United Kingdom through a partnership with Virtualis, Manchester, UK.

We thank former Lifelong Independent Veterinary Education (LIVE) researcher Dr Stephanie Pierce from the Department of Zoology, University of Cambridge, and Dr Vicki Dale, Lecturer in Veterinary Education at LIVE, for their valuable assistance with designing and running this questionnaire.

Kinnison, T., Forrest, N.D., Frean, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

NOTES ON CONTRIBUTORS

TIERNEY KINNISON, M.Sc. is a Research Assistant at the Lifelong Independent Veterinary Education Centre, Royal Veterinary College, University of London, Hatfield, UK. She primarily assists with the design and development of simulators.

NEIL FORREST, B.Sc. (Hons) is a consultant Software Developer and researcher specialising in haptics, currently working for the Royal Veterinary College, University of London, Hatfield, UK.

STEPHEN FREAN, B.V.Sc., Ph.D., MRCVS is a Senior Lecturer in Veterinary Anatomy in the Department of Veterinary Basic Sciences, Royal Veterinary College, University of London, London, UK. He teaches the basic sciences to, primarily, veterinary undergraduate students.

SARAH BAILLIE, Ph.D., MRCVS is a Senior Lecturer in Veterinary Education at the Royal Veterinary College, University of London, Hatfield, UK. She is involved in veterinary educational research with special interest in simulators.

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

LITERATURE CITED

Aziz AM, Mckenzie JC, Wilson JS, Cowie RJ, Ayeni SA, Dunn BK. 2002. The human cadaver in the age of biomedical informatics. *Anat Rec* 269:20-32.

Baillie S, Crossan A, Brewster S, Reid S. 2003. Preliminary development and evaluation of a bovine rectal palpation simulator for training veterinary students. *Cattle Practice* 11:101-106.

Baillie S, Crossan A, Brewster SA, Mellor D, Reid S. 2005a. Validation of a bovine rectal palpation simulator for training veterinary students. *Stud Health Technol Inform* 111:33-36.

Baillie S, Mellor DJ, Brewster SA, Reid SW. 2005b. Integrating a bovine rectal palpation simulator into an undergraduate veterinary curriculum. *J Vet Med Educ* 32:79-85.

Böttcher P, Maierl J, Schiemann T, Glaser C, Weller R, Hoehne K-H, Reiser M, Liebich H-G. 1999. The Visible Animal Project: A three-dimensional, digital database for high quality three-dimensional reconstructions. *Vet Radiol Ultrasound* 40:611-616.

Brenton H, Hernandez J, Bello F, Strutton P, Purkayastha S, Firth T, Darzi A. 2007. Using multimedia and Web3D to enhance anatomy teaching. *Comput Educ* 49:32-53.

Burdea G, Patounakis G, Popescu V, Weiss RE. 1999. Virtual reality-based training for the diagnosis of prostate cancer. *IEEE Trans Biomed Eng* 46(10):1253-1260.

Forrest N, Wall S. 2006. ProtoHaptic: Facilitating Rapid Interactive Prototyping of Haptic Environments. In: *Proceedings of First International Workshop on Haptic and Audio Interaction Design 2006*; Glasgow, UK; 2006 Aug 31- Sept 1; p18-21. Website: <http://protohaptic.googlecode.com> [accessed 01 June 2009].

Garg AX, Norman GR, Eva KW, Spero L, Sharan S. 2002. Is there any real virtue of virtual reality?: The minor role of multiple orientations in learning anatomy from computers. *Acad Med* 77:S97-S99.

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

Hart LA, Wood MW, Weng H-Y. 2005. Mainstreaming alternatives in veterinary medical education: Resource development and curricular reform. *J Vet Med Educ* 32:473-480.

Inwood MJ, Ahmad J. 2005. Development of instructional, interactive, multimedia anatomy dissection software: A student-led initiative. *Clin Anat* 18:613-617.

Issenberg SB, MCGaghie WC, Petrusa ER, Gordon DL, Scalese RJ. 2005. Features and uses of high-fidelity medical simulations that lead to effective learning: A BEME systematic review. *Med Teach* 27:10-28.

Latorre RM, García-Sanz MP, Moreno M, Hernández F, Gil F, López O, Ayala MD, Ramírez G, Vázquez JM, Arencibia A, Henry RW. 2007. How useful is plastination in learning anatomy? *J Vet Med Educ* 34: 172-176.

Levinson AJ, Weaver B, Garside S, McGinn H, Norman GR. 2007. Virtual reality and brain anatomy: A randomised trial of e-learning instructional designs. *Med Educ* 41:495-501.

Linton A, Schoenfeld-Tacher R, Whalen LR. 2005. Developing and implementing an assessment method to evaluate a virtual canine anatomy program. *J Vet Med Educ* 32:249-254.

Martinsen S, Jukes N. 2005. Towards a humane veterinary education. *J Vet Med Educ* 32:454-460.

McLachlan JC, Bligh J, Bradley P, Searle J. 2004. Teaching anatomy without cadavers. *Med Educ* 38:418-424.

McMenamin PG. 2008. Body painting as a tool in clinical anatomy teaching. *Anat Sci Ed* 1:139-144.

Nieder GL, Scott JN, Anderson MD. 2000. Using QuickTime virtual reality objects in computer-assisted instruction of gross anatomy: Yorick-the VR Skull. *Clin Anat* 13:287-293.

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.

Kinnison, T., Forrest, N.D., Freat, S.P., Baillie, S. Teaching Bovine Abdominal Anatomy: Use of a Haptic Simulator. *Anatomical Sciences Education* (2009), 2(6): 280-5.

Parkes R, Forrest N, Baillie S. 2009. A Mixed Reality Simulator for Feline Abdominal Palpation Training in Veterinary Medicine. *Stud Health Technol Inform* 142: 244-6.

Petersson H, Sinkvist D, Wang C, Smedby Ö. 2009. Web-based interactive 3D visualization as a tool for improved anatomy learning. *Anat Sci Educ* 2:61-68.

SimPooch. 2008. <http://www.engr.colostate.edu/ece-sr-design/AY07/SimPooch/index.htm>
Accessed 9th June 2009.

Srinivasan MA, Basdogan C. 1997. Haptics in virtual environments: Taxonomy, research status, and challenges. *Comput Graph* 21:393-404.

SurveyMonkey. 1999. <http://www.surveymonkey.com/> [accessed 16 February 2009]

The Glass Horse. 2001. <http://www.3dglasshorse.com/> [accessed: 06 June 2009].

Williams RL, Srivastava M, Howell JN, Conatser RR, Eland DC, Burns JM, Chila AG. 2004. The Virtual Haptic Back for palpatory training. In: *Proceedings of Sixth ICMI 2004; Pennsylvania, USA; 2004 Oct 13-15; p. 191-197. International Conference on Multimodal Interfaces.*