The Potential of Humane Teaching Methods within Veterinary and Other Biomedical Education

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Summary

Both historically and in many regions today, animal use resulting in harm or death has remained prominent within veterinary and other biomedical education, in disciplines such as surgery, physiology, biochemistry, anatomy, pharmacology, and parasitology. Less well recognized are the harms that also may be experienced by students and staff who participate in such animal use. These range from hazardous exposures to toxic chemical preservatives to psychological and cognitive phenomena that may adversely affect learning and attitudes towards animal welfare. However, in recent years many non-harmful alternatives have been introduced into courses internationally. These include modernized computer simulations, high quality videos, "ethically sourced cadavers" (primarily from animals euthanized for medical reasons), permanently preserved specimens, models, mannequins, advanced surgical and clinical skills simulators, non-invasive self-experimentation, and supervised clinical experiences. Approximately 90% of published educational evaluations have demonstrated that students using humane alternatives achieve superior or equivalent learning outcomes, such as the acquisition of clinical or surgical skills or theoretical knowledge. Many educators remain unaware of the potential offered by humane teaching methods, however, or of the evidence relating to their educational efficacy. Accordingly, this paper reviews the major types of humane teaching methods and the published literature examining their efficacy.

Keywords: 3Rs, education, training, veterinarian, veterinary surgery

1 Introduction

In many educational institutions, animals historically have been and commonly remain the subjects of markedly invasive procedures, which sometimes result in death. These are conducted in order to demonstrate scientific concepts or teach practical skills to students of surgery, anatomy, physiology, biochemistry, pharmacology, and parasitology. Hundreds of humane teaching methods have been developed during the last two decades, and yet many faculty members remain insufficiently aware of their educational potential or of the published literature examining their educational efficacy. Accordingly, this paper reviews the main categories of humane teaching methods in use and illustrates their potential using selected examples. It also reviews relevant educational evaluations and studies.

2 Humane teaching methods

Humane teaching methods utilize computer simulations and videos of professionally performed dissections (*prosections*) and experiments, ethically-sourced cadavers (see following), preserved anatomical specimens, models, mannequins, surgical simulators, non-invasive self-experimentation, and supervised clinical experiences (Knight, 2011).

Computer simulations and videos

Early computer simulations of animal experiments often were criticized for their simplicity (Fig. 1). Modern simulations, however, include video clips of actual experiments and resultant impacts on animals (Figs. 2-3), virtual equipment and body parts, such as nerves and muscles that students may experiment on (Fig. 4).

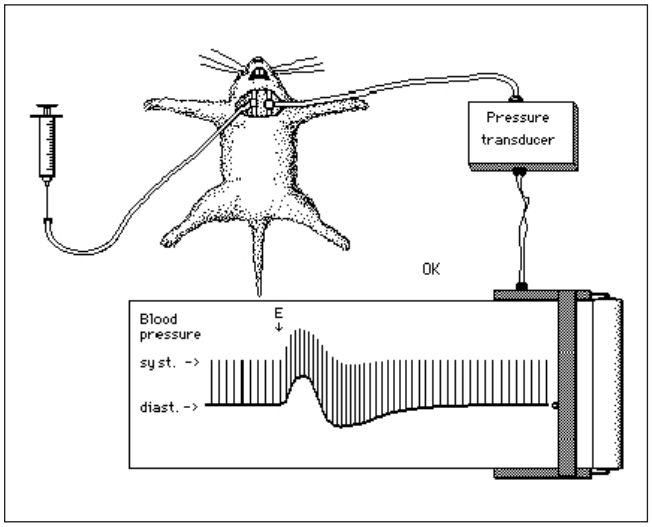


Fig. 1: Early computer simulations were relatively simplistic

Figs. 2-3: Modern simulations may include video clips of animal experiments and resultant effects on animals

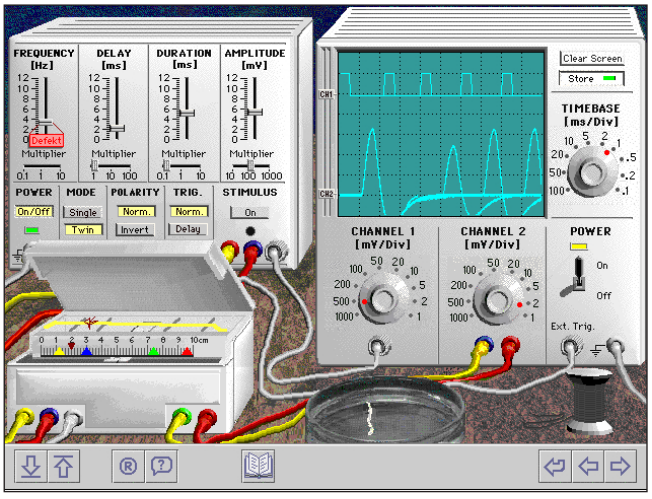


Fig. 4: Modern simulations may include virtual equipment and body parts such as nerves and muscles

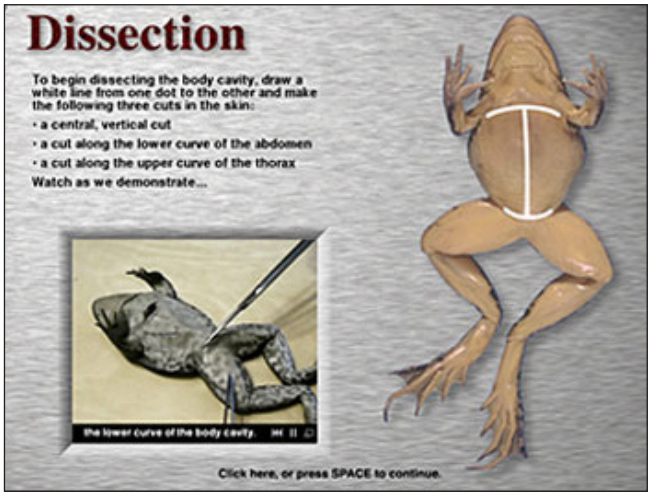


Fig. 5: Dissection simulations may require students to use virtual tools appropriately

Dissection simulations may similarly require students to select appropriate tools from virtual dissecting kits (Fig. 5). Correct choices are rewarded by still images and videos of professionally performed dissections that successfully preserve and display structures sometimes destroyed during student dissections (Fig. 6). Experiments can be repeated as often as desired. *Histological* (microscopic) anatomy may be displayed alongside the *gross* (macroscopic) anatomy of tissues and organs (Fig. 7).

Some simulations are freely available via the internet, such as the "Virtual Canine Anatomy" program provided by the Colorado State University College of Veterinary Medicine and Biomedical Sciences (www.cvmbs.colostate.edu/vetneuro/VCA3/vca.html). The simulation provides key information about many anatomical structures (Fig. 8). Other simulations such as Prodissector's "Face" allow students to contract selected muscles to observe their effects on surrounding tissues (Fig. 9). Simulations may also provide functional diagrams of working organs (Fig. 10), may illustrate radiographic and surface anatomy (Figs. 11-12), and may allow rotation of specimens to obtain different views (Fig. 13). They may even provide information about the natural history of the species in question, including audio clips (Fig. 14).

Non-invasive self-experimentation

Non-invasive experiments may be conducted on oneself or fellow students to investigate and demonstrate physiological principles. In the University of Adelaide medical course, for example, these have been successfully expanded into semester-long

Fig. 6: Professionally performed dissections successfully preserve and display structures sometimes destroyed during student dissections

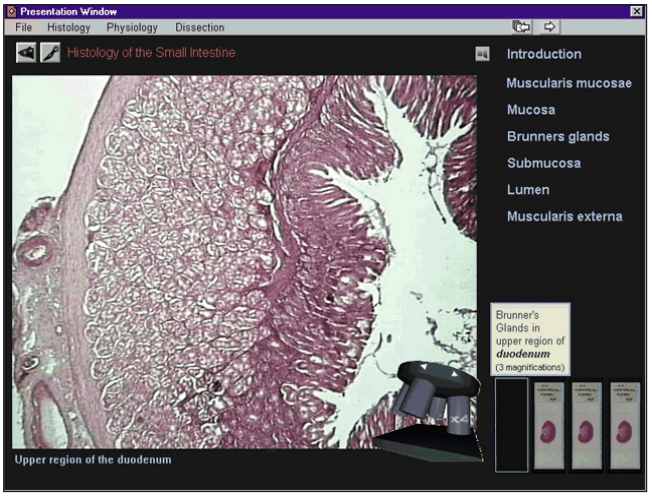


Fig. 7: Histological anatomy may be displayed alongside gross anatomy

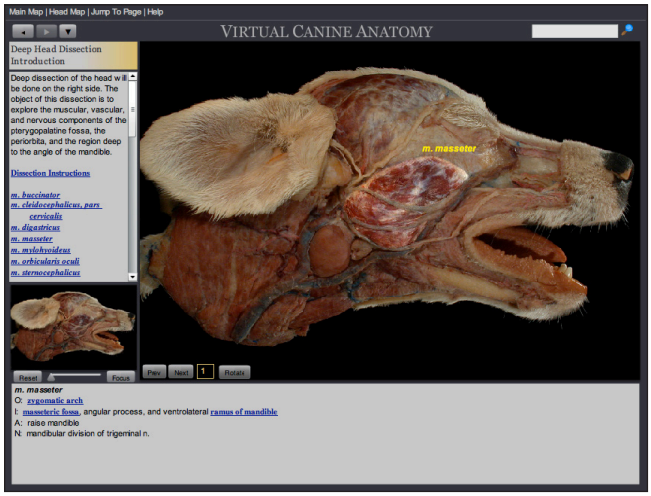


Fig. 8: Simulations may provide information about anatomical structures, such as the points of origin and insertion of muscles, their innervation and function

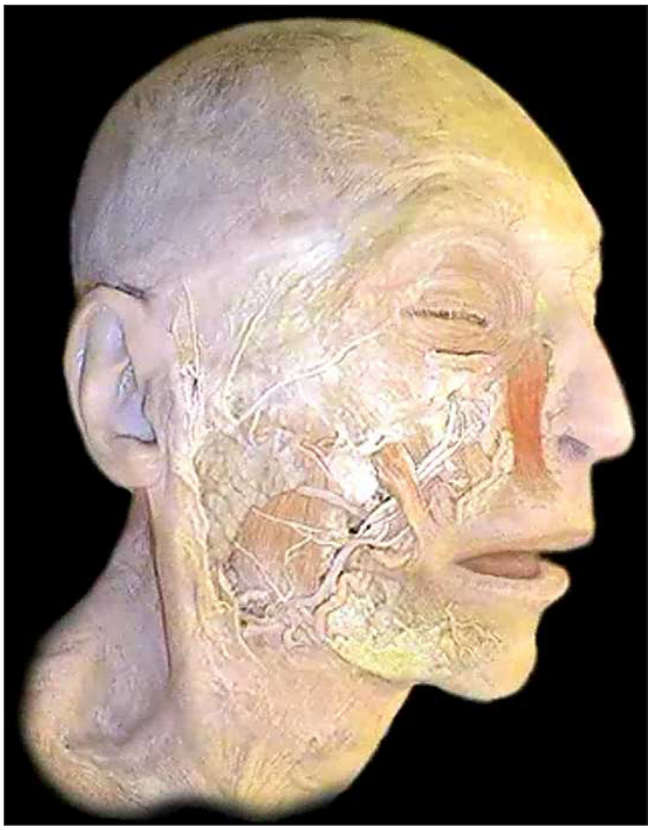


Fig. 9: Prodissector's "Face" simulation allows students to contract selected muscles to observe their effects

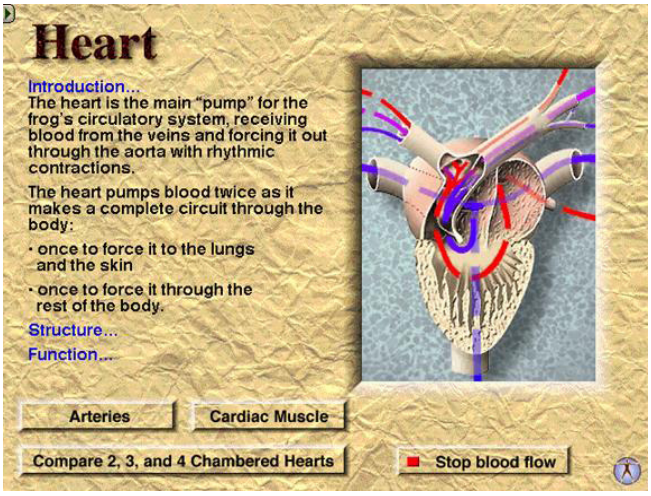


Fig. 10: Simulations may provide functional diagrams of working organs

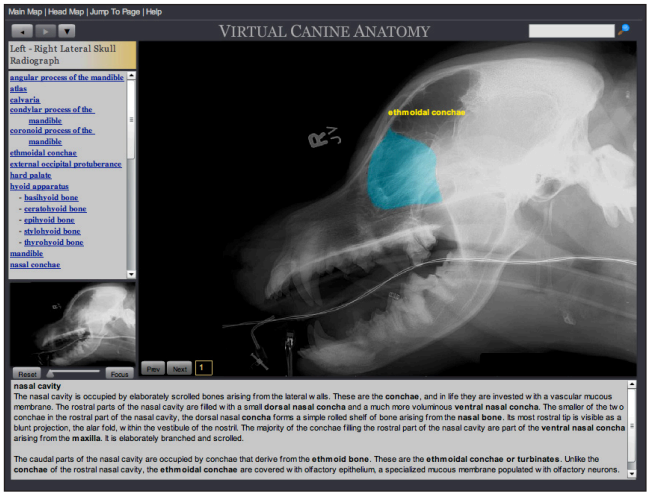


Fig. 11: Simulations may illustrate radiographic anatomy

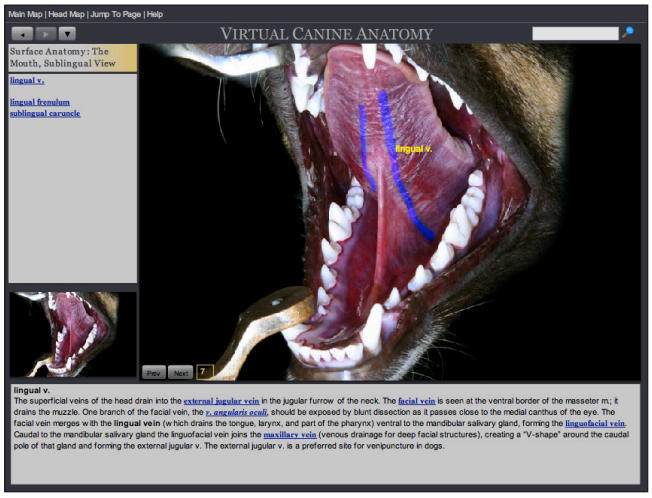


Fig. 12: Simulations may illustrate surface anatomy

Fig. 13: Simulations may allow rotation of specimens to obtain different views

group research projects, allowing practice of important scientific skills, which include preliminary literature reviews, writing ethics committee applications, practical research and data acquisition, statistical analysis, scientific paper authorship, and poster presentations (Scroop, n.d.)

Ethically sourced cadavers

These are obtained from animals that have been euthanized for medical or severe and intractable behavioral reasons, or that have died naturally or in accidents. Client donation programs within veterinary teaching hospitals provide most of these cadavers. At least nine US veterinary schools and some international veterinary schools have established client donation programs in their teaching hospitals (Knight, 2011).

The killing of animals for reasons other than genuine medical or severe and intractable behavioral reasons is ethically controversial, and cadavers obtained through such killing cannot be legitimately classified as ethically sourced. This includes the

Fig. 14: Simulations may provide biological and ecological information, including audio clips

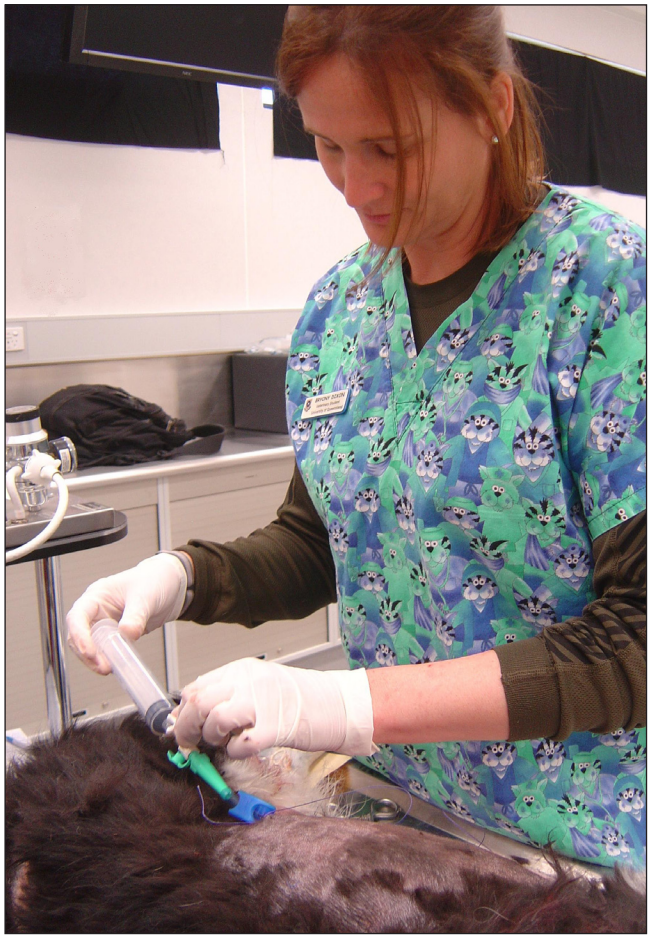


Fig. 15: University of Queensland (UQ) veterinary student Dr Bryony Dixon (who is also a veterinary parasitologist) practices inserting a drain into the thoracic cavity of a dog previously euthanized for medical reasons and donated for teaching purposes
In 2011 Dr Dixon became one of the first UQ students to graduate without participating in harmful animal use.

Fig. 16: The author with a potted, prosected canine head
Such specimens may be permanently preserved using appropriate chemicals.

killing of animals for teaching purposes, in slaughterhouses and animal shelters, and when surplus to the needs of the greyhound racing or animal research industries.

Unlike the relatively anatomically uniform cadavers such as greyhounds often used in anatomy laboratories, ethically sourced cadavers typically demonstrate considerable biological variation, e.g., between dog breeds. They may also allow comparison of normal and pathological tissues and may be accompanied by clinical histories, all of which increases their clinical relevance for veterinary students. They may be used for learning anatomy, practicing clinical skills (Fig. 15), and simulating surgery.

Preserved specimens

Specimens obtained from animal cadavers, whether or not ethically sourced, may be preserved in several ways. This allows their re-use for years, eliminating the need for annual sourcing.

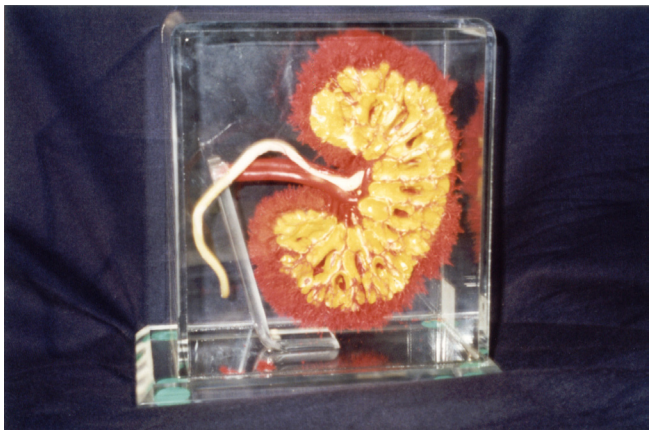
Potted specimens are preserved using formaldehyde or other powerful chemicals designed to prevent tissue dissolution and bacterial putrefaction, in combination with color preservatives (Fig. 16).

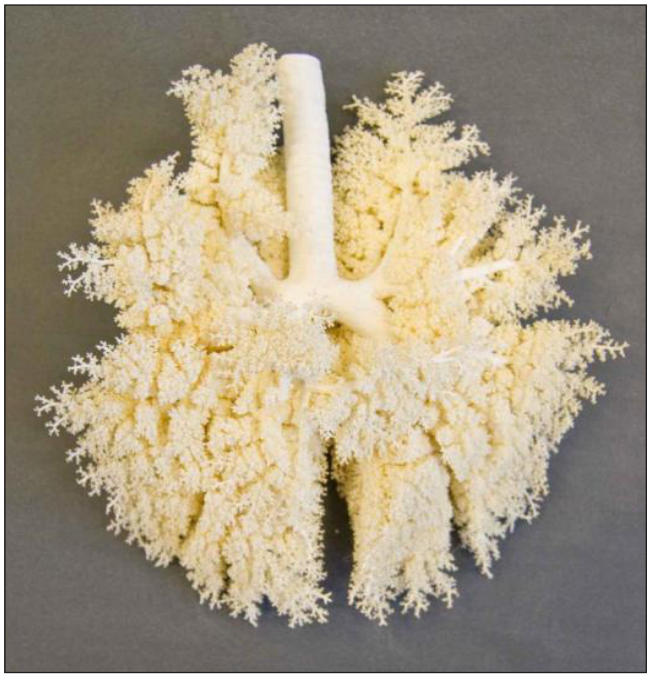
Colored casts of airways and blood vessels may be made after these vessels are perfused with colored dyes, and the surrounding tissues dissolved by mild acids over prolonged periods (Fig. 17-18).

Plastination involves several chemical steps and evacuation. The water and lipids within tissues are replaced by polymers, yielding a plastic texture and removing most of the odor. Very large animals have been successfully plastinated (Fig. 19).

Models, mannequins, and surgical simulators

A wide variety of models and mannequins are designed to illustrate anatomy. Others allow clinical skills training for veterinary or medical students or laboratory technicians. These





Figs. 17-18: Casts of the vasculature of the bovine kidney and the canine tracheobronchial system
Such casts of airways and blood vessels are produced after perfusion with colored dyes. The surrounding tissues are then dissolved by mild acids over prolonged periods.

Fig. 19: Some very large animals have been successfully plastinated
The water and lipids within tissues are replaced by polymers, permanently preserving them.

may include *venipuncture* (blood sampling, using fake blood solutions), endotracheal intubation, thoracocentesis, bandaging, splinting, resuscitation, arterial pulse palpation, and auscultation of heart and breath sounds via a stethoscope (Figs. 20-21).

Surgical simulators include soft-tissue and orthopedic models and mannequins (Figs. 22-23). Systems such as the Pulsating Organ Perfusion Trainer use real organs sourced from slaughterhouses or elsewhere. Their major blood vessels are perfused with blood-colored fluid via a closed circulatory system that includes a pulsatile pump simulating a beating heart. Students and surgeons may practice *hemostatic* (to control hemorrhage) and other surgical techniques, both conventionally and via endoscopic incisions and equipment (Figs. 24-25).

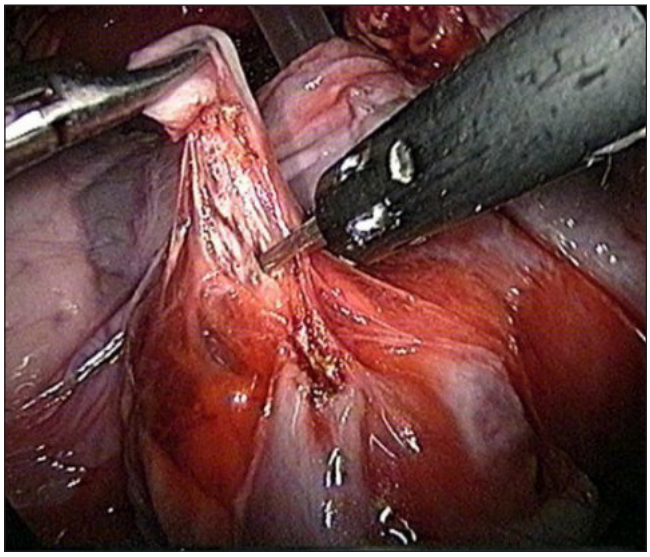
Haptic simulators provide anatomically appropriate tactile feedback to students' instruments and fingers depending on their locations within simulations such as a virtual bovine colon (Fig. 26). They may also be used in endoscopic surgical simulation (Fig. 27).

Supervised clinical experiences

In most countries, veterinary students traditionally have practiced surgical procedures on healthy animals, which they usually kill at the end of the procedure. However, humane surgical courses have now been introduced within many veterinary schools. These ideally comprise several stages. First, students learn basic manual skills such as suturing and instrument han-

Figs. 20-21: Mannequins such as Rescue Critters' "Critical Care Jerry" and "K9 Intubation Trainer" allow veterinary students to practice venipuncture, endotracheal intubation, thoracocentesis, bandaging, splinting, resuscitation and femoral pulse palpation
A wide range of normal and pathological heart and breath sounds may also be auscultated.

Figs. 22-23: Surgical simulators include soft-tissue and orthopedic models and mannequins



Figs. 24-25: The Pulsating Organ Perfusion Trainer uses real organs whose major blood vessels are perfused with colored fluid circulated via a pulsatile pump
Students and surgeons may practice hemostatic and other surgical techniques both conventionally and endoscopically.

Fig. 26: University of Queensland veterinary student Dr Bryony Dixon practices pregnancy diagnosis using a haptic bovine rectal palpation simulator at England's Royal Veterinary College in 2008
The designer, Dr Sarah Baillie, has also created equine colic and feline abdominal palpation simulators.

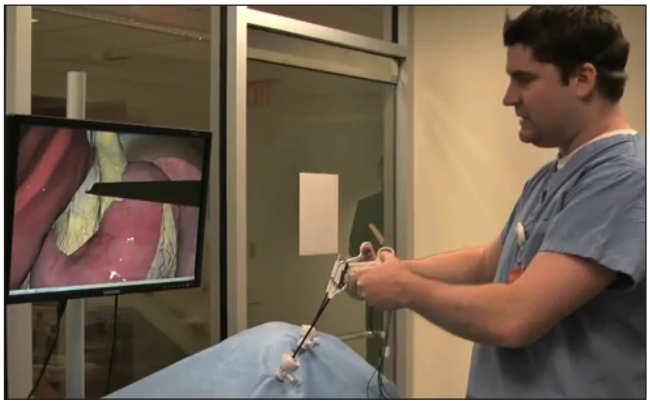


Fig. 27: Haptic simulators may also be used in endoscopic surgical training
They provide anatomically appropriate tactile feedback to the surgeon's instruments and fingers.

dling, using knot-tying boards, plastic organs, and similar models. They then progress to simulated surgery on ethically sourced cadavers. Finally, students observe, assist with, and then perform necessary surgery under close supervision on real patients that actually benefit from the surgery, similar to the manner in which physicians are trained (Knight, 2011).

Animal shelter neutering programs are a popular component of humane veterinary surgical courses worldwide. The students gain invaluable experience of some of the most common procedures they will later perform in practice (Richardson et al., 1994, Howe and Slater, 1997), the number of unwanted animals killed due to uncontrolled breeding and a subsequent lack of homes is decreased, and neutered animals are more likely to be adopted (Clevenger and Kass, 2003).

3 Educational efficacy

Comparative studies: veterinary surgical training
The introduction of humane teaching methods within curricula frequently has been accompanied by educational evaluations that subsequently have been published. These often have compared learning outcomes achieved by newly introduced humane teaching methods with those achieved via traditional harmful animal use.

At least eleven such studies have examined the learning outcomes of veterinary students. Nine have assessed surgical training – historically the area of greatest harmful animal use. The humane surgical teaching methods used included models or surgical simulators, and cadavers. In 45.5% of cases (5/11) supe-

rior learning outcomes (superior skill or knowledge, or equivalent performance with reduced activity times) resulted from the use of the humane option; equivalent learning outcomes also resulted in five cases, and in one case (9.1%) the humane option resulted in inferior learning outcomes (Knight, 2011).

Skills assessed in surgical laboratories included basic surgical skills such as psychomotor and ligation skills, as well as key abdominal surgical skills such as intestinal anastomoses and celiotomy closures, gastrostomy closures, and ovariohysterectomies. Overall, the surgical skills generated by these humane alternatives were at least equivalent to those achieved via traditional harmful animal use.

Three surgical studies demonstrated superior surgical skills when humane alternatives were used. Olsen and colleagues (1996), for example, demonstrated that a fluid hemostasis model was at least as effective as a live dog splenectomy for teaching blood vessel ligation and division. In fact, students using the model completed their ligatures more quickly, with fewer errors. They successfully tied more square knots, their ligatures were tighter, and their instrument grip was superior. These students' initial skepticism regarding the use of properly designed inanimate models for teaching these surgical skills was dramatically altered.

Five studies demonstrated equivalent surgical skills when humane alternatives were compared to harmful animal use.

One study demonstrated inferior surgical skill acquisition using the humane option. Smeak and colleagues (1994) compared live animal gastrostomy skills of two groups of 20 students, one of which had practiced the procedure using a hollow organ model, and the other of which had practiced using a live animal. While they found no significant difference in overall gastrostomy closure technique, the students performing the procedure for a second time on a live animal were significantly quicker. Anesthetic time is an important surgical consideration; hence this was considered a superior learning outcome. However, the plastic model used in this study was deficient, being more fragile and stiff than living gastric tissue, with suture pull-through occurring despite appropriate technique and tension; even though the model was found to be effective for teaching instrument use, needle placement, atraumatic tissue handling and tissue inversion. This example demonstrates the need to ensure that humane teaching methods are well designed.

Comparative studies: other veterinary disciplines

Surgery and physiology are historically the disciplines that have resulted in the greatest harmful animal use during veterinary education. Disciplines other than surgery were poorly represented in studies of veterinary students.

Abutarbush and colleagues (2006) found that a CD-ROM was more effective than a live animal demonstration by an instructor of the correct method for inserting a nasogastric tube into a horse. Students using the CD-ROM performed significantly better on a test of knowledge, were more confident, and were significantly quicker at successfully inserting a nasogastric tube into a live horse, than their traditionally instructed peers.

Fawver and colleagues (1990) found that first year veterinary students learned cardiovascular physiology principles more efficiently from interactive videodisc simulations than from live animal laboratories, resulting in both student and staff time savings.

Comparative studies: non-veterinary disciplines

At least 21 papers have described studies of non-veterinary students in related academic disciplines, similarly comparing learning outcomes generated by humane alternatives with those achieved by traditional harmful animal use. Seven of these studies have examined high school biology students, and 14 have examined university biology, medical, nursing, pharmacology, physiology, and psychology students. The seven studies of high school biology students examined anatomical knowledge gained using alternatives to the dissection of purpose-killed animals. Three studies demonstrated superior, three studies demonstrated equivalent, and one study demonstrated inferior knowledge acquisition when humane alternatives were used (Knight, 2011).

Of the 14 studies examining university students, 35.7% (5/14) demonstrated that students using humane alternatives achieved superior learning outcomes, or achieved equivalent results more quickly, allowing time for additional learning; 57.1% (8/14) demonstrated equivalent educational efficacy, and only one study (7.1%) demonstrated inferior educational efficacy of humane alternatives (Knight, 2011).

Non-comparative studies

Numerous additional publications not involving comparisons with harmful animal use have illustrated additional benefits of humane teaching methods (Knight, 2011). For example, students using such methods also have demonstrated superior understanding of complex biological processes and increased examination results, along with more peripheral benefits such as increased confidence and decreased stress.

Increased teaching and learning efficiency and decreased costs, along with enhanced potential for customization and repeatability of learning exercises, are common findings. The former logistical benefits are the major factors increasing the implementation of humane teaching methods internationally, and the latter benefits are the most likely causes of the improved learning outcomes achieved by a substantial minority of humane teaching methods.

4 human impacts of harmful animal use

The harms inflicted on animals used for educational purposes are well recognized: the animals commonly are subjected to markedly invasive procedures or are killed.

Less well recognized the potential adverse impacts on participating students and staff. Anatomy specimens usually are preserved using highly toxic chemicals that create significant health hazards as well as subsequent potential for legal and fi-

nancial liability should adverse exposure-related effects result. In the experience of this author and colleagues from leading veterinary schools internationally, recommended safety guidelines such as the use of gloves, gowns, and masks often are complied with only partially (Knight, 2007).

For many students, participation in harmful live animal use, such as that occurring in physiology demonstration or surgical training laboratories, generates powerful emotional experiences and high levels of stress. These have considerable potential to adversely affect cognitive processes such as learning. Veterinary student surveys indicate that students often are distracted from relevant scientific concepts by the plight of their animals and the necessity of concentrating on maintaining life and anesthetic depth. A minority of students, however, consider such experiences beneficial for learning (Knight, 2011).

Additionally, faculty opposition to student desires for humane teaching methods has been common internationally, frequently resulting in conflict. Adverse effects have included considerable time and financial costs, damage to relationships between students and faculty sufficient to markedly affect learning, student expulsions, lawsuits against universities, and significant adverse publicity (Knight, 2011).

Over time, student participation in harmful animal use appears to contribute to a range of desensitization-related phenomena, which adversely affect awareness of animal welfare problems and the desire to take appropriate action to redress them. Such adverse attitudinal impacts have the potential to decrease the ability of veterinarians to safeguard and promote good welfare for their patients and animals generally (Knight, 2011).

5 Conclusions

Comparative studies of student learning outcomes from a wide variety of disciplines and educational levels indicate that well designed humane alternatives usually perform at least as well as methods that rely upon harmful animal use. Indeed, they achieve superior learning outcomes in a substantial minority of studies, probably because of their enhanced potential for repeatability and customization of learning exercises, and through reduced student stress and distraction. Furthermore, the great majority of published comparative studies is more than a decade old and describes methods that have been largely superseded by more advanced alternatives, particularly in the field of computer simulations. The animal laboratories these alternatives were designed to replace, such as dissections and experimental or surgical laboratories, have, on the other hand, remained largely unaltered. It is probable that comparative studies of modern humane teaching methods would yield an even higher proportion of studies demonstrating superior learning outcomes when compared to harmful animal use (Knight, 2011).

Other important benefits of humane teaching methods include increased compliance with animal use legislation or regulations, elimination of student and faculty objections to the use of purpose-killed animals, and integration of clinical perspectives and ethics early within curricula. Significant time and cost savings also are common.

Substantial numbers of animal lives are saved as well, and some evidence suggests that veterinarians trained without harmful animal use may develop higher animal welfare standards, potentially benefiting their future patients. Those who participate in animal shelter neutering programs may also gain increased understanding of the pet overpopulation problem and the role of the veterinarian in combating it.

Detailed information about the alternatives available for various academic disciplines is provided by Jukes and Chiuia (2003), and by sites such as www.vetmed.ucdavis.edu/Animal_Alternatives/main.htm and www.clive.ed.ac.uk. Synopses of surgical simulators designed for medical students and practitioners are provided at www.virtualsurgery.vision.ee.ethz.ch. Links to libraries from which a variety of alternatives may be borrowed, along with free online computer simulations, comprehensive alternatives databases, academic reviews of leading alternatives, and hundreds of educational studies of alternatives organized by discipline, also are available through: www.HumaneLearning.info, www.InterNICHE.org, and www.EURCA.org

References

Abutarbush, S. M., Naylor, J. M., Parchoma, G., et al. (2006). Evaluation of traditional instruction versus a self-learning computer module in teaching veterinary students how to pass a nasogastric tube in the horse. *J. Vet. Med. Educ. 33*, 447-454.

Clevenger, J. and Kass, P. H. (2003). Determinants of adoption and euthanasia of shelter dogs spayed or neutered in the University of California veterinary student surgery program compared to other shelter dogs. *J. Vet. Med. Educ. 30*, 372-378.

Fawver, A. L., Branch, C. E., Trentham, L., et al. (1990). A comparison of interactive videodisc instruction with live animal laboratories. *Amer. J. Physiol. 259*, 11-14.

Howe, L. M. and Slater, M. R. (1997). Student assessment of the educational benefits of a prepubertal gonadectomy program (preliminary findings). *J. Vet. Med. Educ. 24*, 12-17.

Jukes, N. and Chiuia, M. (2003). *From Guinea Pig to Computer Mouse: Alternative Methods for a Progressive, Humane Education*. 2nd edition. Leicester, UK: InterNICHE. http://www.interniche.org/en/resources/book (accessed 15.02.2012).

Knight, A. (2007). The effectiveness of humane teaching methods in veterinary education. *ALTEX 24*, 91-109.

Knight, A. (2011). *The costs and benefits of animal experiments*. Basingstoke, UK: Palgrave Macmillan.

Olsen, D., Bauer, M. S., Seim, H. B., and Salman, M. D. (1996). Evaluation of a hemostasis model for teaching basic surgical skills. *Vet. Surg. 25*, 49-58.

Richardson, E. F., Gregory, C. R., and Sucre, E. (1994). Enhancement of the surgical education of fourth year veterinary

students by participation in juvenile ovariohysterectomy and castration program. *Vet. Surg. 23*, 415.
Scroop, G. (no date). *Research project practicals in the department of physiology*. Adelaide: The University of Adelaide.
Smeak, D. D., Hill, L. N., Beck, M. L., et al. (1994). Evaluation of an autotutorial-simulator program for instruction of hollow organ closure. *Vet. Surg. 23*, 519-528.

Acknowledgements
My presentations at the Eighth World Congress on Alternatives and Animal Use in the Life Sciences were funded by the conference organizers. I am grateful for their support and the invitation to speak. Figures 15 and 26 were supplied by Dr Bryony Dixon of the University of Queensland, and Figure 18 by Prof. Amarendhra Kumar of the Tufts University Cummings School of Veterinary Medicine. I am grateful for their assistance.

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