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Humane teaching methods prove efficacious within veterinary and other biomedical education

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Abstract
Animal use resulting in harm or death remains common within veterinary education, in disciplines such as surgery, physiology, biochemistry, anatomy, pharmacology, and parasitology. However, many non-harmful alternatives now exist, including computer simulations, high quality videos, 'ethically-sourced cadavers,' such as from animals euthanized for medical reasons, preserved specimens, models and surgical simulators, non-invasive self-experimentation, and supervised clinical experiences. Studies of veterinary students were reviewed comparing learning outcomes generated by non-harmful teaching methods with those achieved through harmful animal use. Of eleven published from 1989 to 2006, nine assessed the acquisition of surgical skills. 45.5% (5/11) demonstrated superior learning outcomes using more humane alternatives. Another 45.5% (5/11) demonstrated equivalent learning outcomes, and 9.1% (1/11) demonstrated inferior learning outcomes. Twenty one studies of non-veterinary students in related academic disciplines were also published from 1968 to 2004. 38.1% (8/21) demonstrated superior, 52.4% (11/21) demonstrated equivalent, and 9.5% (2/21) demonstrated inferior learning outcomes using humane alternatives. Twenty nine papers in which comparison with harmful animal use did not occur illustrated additional benefits of humane teaching methods within veterinary and other biomedical education. Educators can best serve their students and animals, while minimizing financial and time burdens, by introducing well-designed teaching methods not reliant on harmful animal use.

Keywords: alternative, animal experiment, education, veterinarian, veterinary surgery

Introduction

Animal use resulting in harm or death has historically played an integral role in veterinary education worldwide, in disciplines such as surgery, physiology, biochemistry, anatomy and pharmacology. However, many non-harmful alternatives now exist, including computer simulations, high-quality videos, *ethically-sourced cadavers* from animals that have been euthanized for medical reasons, or have died naturally or in accidents, preserved specimens, models and surgical simulators, non-invasive self-experimentation, and supervised clinical experiences (Rowan, 1991; Bauer, 1993; Knight, 1999; Kumar *et al.,* 2001; Gruber & Dewhurst, 2004; Martinsen & Jukes, 2006).

Humane veterinary surgical courses ideally comprise several stages. Students learn basic manual skills such as suturing and instrument handling 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—as distinct from on healthy animals that are later killed—similar to the manner in which physicians are trained (Knight, 1999). Animal shelter sterilization programs are a popular component of many humane veterinary surgical courses worldwide (Richardson *et al.*, 1994; Howe and Slater, 1997).

Faculty opposition to humane teaching methods

Protracted struggles by veterinary students around the world have shown that some veterinary academics remain opposed to the introduction of humane teaching methods. While a veterinary student at Western Australia's Murdoch University in 1998, I had to initiate legal action and media exposure of curricular animal killing before Murdoch allowed their use. To its considerable credit, Murdoch then responded positively by introducing Australia's first formal policy allowing conscientious objection by students, agreeing to provide them with humane learning and assessment activities on request. Similar policies have since been adopted by other universities within Australia and abroad.

In 2000, a classmate and I became Western Australia's first veterinary students to win the right not to have to kill animals in our fourth-year

terminal surgical laboratory classes, under Murdoch's conscientious objection policy. To my knowledge, ours was the only alternative veterinary surgical course worldwide in which the academics charged with providing non-harmful practical instruction refused to do so, because of their opposition to the concept, instead requiring students to arrange their own instruction outside the university in private clinics and animal shelters. Despite this, we succeeded, gaining five times the surgical experience of our classmates who killed to obtain their degrees. Included were 21 dog and cat spays. It felt wonderful to be contributing positively toward the dog and cat overpopulation problem through neutering, thereby preventing unnecessary deaths, instead of causing them during our surgical training.

Since then, veterinary student colleagues at all of Australia's other established veterinary schools have experienced similar opposition when requesting humane learning methods. Some were nevertheless successful, with the result that by 2005 the first students had graduated from all four established Australian veterinary schools without killing animals during their surgical training. The University of Sydney went further, entirely eliminating all terminal surgical laboratories in 2000.

Faculty opposition to humane teaching methods is by no means a uniquely Australian phenomenon. In 2002 the United States Department of Agriculture cited nearly every US veterinary school for non-compliance with the federal Animal Welfare Act. Most citations were issued for failing to search for alternatives to harmful or lethal animal use, or for failing to provide adequate explanations as to why non-harmful alternatives were not used (Anon, 2005). Reports from students in other countries have demonstrated that faculty opposition to the use of humane teaching methods occurs internationally, and that it is also evident in non-veterinary courses (Knight, 2007).

Some interesting psychological phenomena may explain the marked resistance of some faculty members to humane teaching methods. Maintenance of a belief in their invalidity may be necessary to avoid personal guilt associated with the large-scale killing of animals in veterinary courses. Gruber and Dewhurst (2004) further asserted that: *"Human vanity is also a factor that should not be underestimated. For many university teachers it is not acceptable to diverge from the methods one was taught and which one has always used in a life of teaching. Aversion towards accepting alternatives that were not developed in one's own country also plays a role."*

Systematic reviews of veterinary student learning outcomes

Nevertheless, the reasons most commonly cited by academics opposed to humane teaching methods are concerns about their educational efficacy. Accordingly, a recent review by Patronek and Rauch (2007) was illuminating. Patronek and Rauch reviewed studies of biomedical student learning outcomes achieved by humane teaching methods in comparison to terminal live animal use. Of seventeen studies located, five examined veterinary students, three examined medical students, six examined other undergraduate students and three examined high school biology students. For two of these studies of medical students, equivalent learning outcomes were achieved using alternatives to the dissection of human cadavers, and harmful animal use may not have occurred (Jones *et al.,* 1978; Guy and Frisby, 1992).

Of the remaining 15 studies clearly involving comparisons with harmful animal use, four resulted in superior, and eleven resulted in equivalent learning outcomes, when humane teaching methods were used. Of the five veterinary student studies, two resulted in superior surgical skill acquisition when alternatives to terminal live animal use were employed, and three resulted in equivalent learning outcomes when alternatives to harmful animal use were employed in surgical and physiology courses. Consequently, Patronek and Rauch concluded that *"alternatives are a viable method of instruction in the field of biomedical education."*

Potentially harmful non-terminal animal use was not considered, however, such as equine nasogastric intubation when conducted by novices, and repetitive bovine rectal palpation, both of which may occur during veterinary training. Additionally, the search parameters were used not exhaustive. Consequently, I conducted a more comprehensive systematic review of studies of veterinary student learning outcomes.

Methods

The peer-reviewed biomedical literature was searched for studies comparing the learning outcomes achieved by veterinary students trained using non-harmful teaching methods, to those achieved through harmful animal use. To ensure comprehensive coverage, six biomedical bibliographic databases were searched: CAB Abstracts, which is the most comprehensive bibliographic database for the applied life sciences; the Cochrane Central Register of Controlled Trials, which is a bibliographic database of definitive controlled trials produced by the Cochrane Collaboration (www.cochrane.us), in cooperation with the National Library of Medicine in Washington, DC; the Cochrane Database of Systematic Reviews, which is the main component of the Cochrane Library; the Cumulative Index to Nursing & Allied Health database, which provides authoritative coverage of the literature related to nursing and allied health; EMBASE, the Excerpta Medica database,

which is a biomedical and pharmacological database; and MEDLINE, the United States National Library of Medicine's premier bibliographic database, covering veterinary medicine and many other biomedical disciplines. Jointly these databases included over 15 million citations from the mid 1950s onwards, sourced from more than 6,000 biomedical journals from over 140 countries (CABI, n.d. a-b; United States Cochrane Center, n.d.; CINAHL information systems, 2005; EMBASE, 2007; NCBI, 2006).

All titles, abstracts, subject headings, and other key fields were searched for "endoscopic simulation" or "endoscopy simulation" or "endoscopic simulator" or "endoscopy simulator" or "surgery simulation" or "surgical simulation" or "surgery simulator" or "surgical simulator" or "veterinary curriculum" or "veterinary education" or "veterinary physiology" or "veterinary student" or "veterinary surgery." These search terms were chosen partly because endoscopic simulators comprise a large and important sub-category within the field of surgical simulators, and because both historically and contemporarily veterinary physiology and surgery have been the disciplines in which the greatest harmful use occurs, and consequently, in which the greatest efforts to introduce humane alternatives have also occurred.

The abstracts, and, on occasion, complete papers, were examined to locate studies of veterinary and non-veterinary student performance achieved using humane alternatives, in comparison to harmful animal use. Cited references of retrieved papers were also reviewed to identify additional relevant papers. Additionally, the main reference books within this field were searched (Balcombe, 2000; Knight, 2002; Jukes & Chiuia, 2003).

For the purposes of this review, animal use considered harmful included: invasive procedures, or those reasonably likely to be significantly stressful, such as equine nasogastric intubation (when conducted by novice practitioners); most physiology, pharmacology and biochemistry demonstration laboratories using live animal subjects or living tissue from recently killed animals; surgical procedures other than those described below; and any use of animals resulting in death, other than genuine euthanasia performed solely for medical or severe and intractable behavioral reasons; and the dissection of purpose-killed animals.

Animal use considered non-harmful included: observation of wild, feral or companion animals in field studies or elsewhere; minimally-invasive or stressful procedures conducted on living animals, such as bovine rectal palpation (although repeated use in some veterinary practical classes can become stressful and/or harmful); invasive procedures conducted for the benefit of genuine animal patients or populations, such as neutering operations and similarly beneficial elective surgeries performed on healthy animals, and emergency surgeries conducted on injured or unwell animals; and dissection, clinical or surgical procedures performed on ethically-sourced cadavers, including the cadavers of humans donated for use in medical education.

With respect to studies of veterinary surgical training, in which surgery performed on living animals was compared with that conducted on cadavers or inanimate models, the source of the cadavers was unspecified in most studies. However, cadavers are usually obtained from ethically-questionable sources, such as the greyhound racing industry and animal control agencies ('pounds'). Consequently, when compared with a non-animal alternative (e.g., Griffon *et al.,* 2000), the latter was considered the more humane option for the purposes of this review. However, cadavers may also be ethically-sourced, and growing minority of veterinary schools have established client donation programs in their teaching hospitals for this purpose (Knight, 2007). Given their potential for ethical-sourcing when compared with terminal live animal use (the norm in veterinary surgical training), a cadaver was considered the more humane option.

Results

As of 22 Dec. 2006, 3954 biomedical database records were located using the specified search terms. Of these, 12 papers published from 1989 to 2006 described studies of veterinary students comparing learning outcomes generated by humane alternatives with those achieved by traditional harmful animal use (Table 1). Greenfield and colleagues (1994, 1995) described the same study; hence 11 distinct studies of veterinary student learning outcomes were retrieved. Nine of these veterinary student studies assessed surgical training—historically the field involving the greatest harmful animal use. In 45.5% (5/11) of cases, superior 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 45.5% (5/11) of cases; and in one case (9.1%) the humane option resulted in inferior learning outcomes (Knight, 2007).

Twenty one papers published from 1968 to 2004 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 (Table 2). Seven of these studies of related non-veterinary disciplines examined high school biology students, while 14 examined undergraduate biology, medical, nursing, pharmacology, physiology or psychology students. The seven studies of high school biology students published from 1968 to

Table 1: Veterinary student learning outcomes: humane teaching methods compared to harmful animal use

	Study	Veterinary discipline	Humane option	Total students (humane option)	Humane method superior	Equivalent learning outcomes	Humane method inferior
1	Abutarbush *et al.* 2006	clinical skills (equine)	CD-ROM	52 (27)	✓		
2	Bauer *et al.* 1992	surgery	cadavers			✓	
3	Carpenter *et al.* 1991	surgery	cadavers	24		✓	
4	Fawver *et al.* 1990	physiology	interactive videodisc	85	✓		
5	Greenfield *et al.* 1994	surgery	soft tissue organ models	36		✓	
6	Greenfield *et al.* 1995	surgery	soft tissue organ models	36		✓	
7	Griffon *et al.* 2000	surgery	plastic models	40 (20)	✓		
8	Johnson & Farmer 1989	surgery	models		✓		
9	Olsen *et al.* 1996	surgery	fluid hemostasis models	40 (20)	✓		
10	Pavletic *et al.* 1994	surgery	cadavers	48 (12)		✓	
11	Smeak *et al.* 1994	surgery	hollow organ simulators	40 (20)			✓
12	White *et al.* 1992	surgery	unspecified "alternative surgical program"			✓	
	Totals				**5**	**6**	**1**

2004 examined anatomical knowledge acquired through 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, 2007).

Of the 14 studies examining undergraduate students published from 1983 to 2001, 35.7% (5/14) demonstrated that alternative students achieved superior learning outcomes, or achieved equivalent results more quickly, allowing time for additional learning. 57.1% percent (8/14) demonstrated equivalent educational efficacy, and only one study (7.1%) demonstrated inferior educational efficacy of humane alternatives (Knight, 2007).

Twenty nine papers published from 1983 to 2006 not involving comparisons with harmful animal use were also identified (Table 3), illustrating additional benefits of humane teaching methods, including time and cost savings, enhanced potential for customization and repeatability of learning exercises, increased student confidence and satisfaction, increased compliance with animal use legislation, elimination of objections to the use of purpose-killed animals, and integration of clinical perspectives and ethics early within curricula (Knight, 2007). All of these studies may be viewed at www.HumaneLearning.info, 'published papers, comparative'.

Discussion

Comparative studies: Chronological implications

Of the 11 studies comparing veterinary student learning outcomes, eight were more than a decade old (published prior to 1996). Of the 21 papers describing non-veterinary student learning outcomes, 18 were more than a decade old. Hence, a considerable number of these studies examined humane teaching methods such as films, interactive video discs, and early computer simulations, which have been largely superseded by more advanced alternatives, particularly in the field of computer simulations. The laboratories these alternatives were designed to replace, such as animal dissections and live animal experimental or surgical laboratories, have, on the other hand, remained largely unaltered. It is a damning indictment of harmful animal use that even such relatively antiquated alternatives resulted in superior or equivalent learning outcomes in almost all cases. It is likely that comparative studies of modern alternative teaching methods would yield an even higher proportion of studies demonstrating superior learning outcomes when compared to harmful animal use.

Table 2: Non-veterinary student learning outcomes: humane teaching methods compared to harmful animal use							
	Study	Discipline	Humane option	Total students (humane option)	Humane method superior	Equivalent learning outcomes	Humane method inferior
1	Cohen & Block 1991	psychology	field study (feral pigeons)			✓	
2	Clark 1987	physiology	computer simulation			✓	
3	Cross & Cross 2004	biology (high school)	computer simulation	74 (38)			✓
4	Dewhurst *et al.* 1988	physiology	computer simulation	~80 (~40)		✓	
5	Dewhurst & Meehan 1993	physiology	computer simulations	65 (~33)		✓	
6	Dewhurst *et al.* 1994	physiology	computer simulation	14 (6)		✓	
7	Downie & Meadows 1995	biology (undergraduate)	models (rats)	2,913 (308)		✓	
8	Fowler & Brosius 1968	biology (high school)	video	156	✓		
9	Henman & Leach 1983	pharmacology	biovideograph videotape recordings	50	✓		
10	Hughes 2001	pharmacology	computer simulations			✓	
11	Kinzie *et al.* 1993	biology (high school)	interactive videodisc	61		✓	
12	Leathard & Dewhurst 1995	physiology (medicine)	computer simulation	156		✓	
13	Leonard 1992	biology (undergraduate)	interactive videodisc	142	✓		
14	Lieb 1985	biology (high school)	lecture			✓	
15	Matthews 1998	biology (undergraduate)	computer simulation	20 (12)			✓
16	McCollum 1987	biology (high school)	lecture	350 (175)	✓		
17	More & Ralph 1992	biology (undergraduate)	computer courseware	184 (92)	✓		
18	Phelps *et al.* 1992	physiology (nursing)	interactive videodisc		✓		
19	Samsel *et al.* 1994	physiology (medicine)	computer simulations	110	✓		
20	Strauss & Kinzie 1994	biology (high school)	interactive videodisc	34 (17)		✓	
21	Velle & Hal 2004	biology (high school)	computer simulation	64	✓		
	Totals				**8**	**11**	**2**

Other advantages of humane teaching methods

Besides saving substantial numbers of animal lives, humane teaching methods increase compliance with legislative requirements to minimize harmful animal use. Additionally, some evidence indicates that veterinary education may result in the decreased likeliness of students to view animals as sentient, in decreased empathy toward animals, in decreased propensity to administer peri-operative analgesics, and even in the impedance of moral reasoning ability (Self *et al.*, 1991 & 1996; Hellyer *et al.*, 1999; Paul & Podberscek, 2000; Levine *et al.*, 2005). Along with inadequate curricular attention to animal welfare science, the human-animal bond and the development of critical reasoning ability and ethics (Self *et al.*, 1994; Williams *et al.*, 1999), the harmful

Table 3: Additional benefits of humane teaching methods in veterinary education				
	Study	Veterinary discipline	Humane option	Benefits of humane option (other than decreased harmful animal use)
1	Allen & Chambers 1997	surgery	computerized tutorial	increased surgical skill
2	Baillie *et al.* 2003	clinical skills (bovine)	virtual reality simulator	customization of learning experience, repeatability, superior skill acquisition and development
3	Baillie *et al.* 2005a	clinical skills (bovine)	virtual reality simulator	customization of learning experience, repeatability, superior skill acquisition and development
4	Baillie *et al.* 2005b	clinical skills (bovine)	virtual reality simulator	customization of learning experience, repeatability, superior skill acquisition and development
5	Buchanan *et al.* 2005	biochemistry	3D animations	superior understanding of complex biological processes
6	Dhein & Memon 2003	continuing education	internet based curriculum	overcomes obstacles of time and distance, decreased costs, facilitates lifelong learning
7	Dyson 2003	anesthesia	CD-ROM	increased anesthetic knowledge
8	Ellaway *et al.* 2005	unspecified	virtual learning environment	increased flexibility of use
9	Erickson & Clegg 1993	physiology	computer simulations	greatest student satisfaction
10	Galle & Bubna-Littitz 1983	clinical skills (canine)	cadaver	repeatability
11	Greenfield *et al.* 1994	surgery	models	decreased student and faculty objections to harmful animal use
12	Hawkins *et al.* 2003	clinical skills (small animal)	video	increased diagnostic skills
13	Hines *et al.* 2005	pathology (systemic)	virtual learning environment	greater understanding, student satisfaction, increased flexibility of use
14	Holmberg *et al.* 1993	surgery	model	decreased student stress, repeatability
15	Howe & Slater 1997	surgery	sterilization program	increased surgical and anesthetic skills including atraumatic tissue handling, increased understanding of the pet overpopulation problem and the role of the veterinarian in combating it, increased awareness of the activities of humane organizations
16	Howe *et al.* 2005	surgery	CD-ROM	increased practice of techniques, enhanced preparedness for laboratories, greater student satisfaction
17	Josephon & Moore 2006	anatomy	DVD	customization of learning experience to individual needs, possibly increased examination results
18	Kumar *et al.* 2001	anatomy	ethically-sourced cadavers	compliance with animal use regulations, elimination of student and faculty objections to the use of purpose-killed animals, integration of clinical perspectives and ethics early in the curriculum
19	Linton *et al.* 2005	anatomy	computer simulation	rapid access to related views such as radiographs, increased learning efficiency and student confidence
20	Modell *et al.* 2002	anesthesia	human patient simulator	realism, increased confidence coping with complex clinical problems, increased examination results
21	Mori *et al.* 2006	surgery	model	repeatability, increased surgical skill
22	Pinkney *et al.* 2001	parasitology	computer tutorial	increased examination scores
23	Richardson *et al.* 1994	surgery	sterilization program	increased surgical and anesthetic skills including atraumatic tissue handling, increased understanding of the pet overpopulation problem and the role of the veterinarian in combating it, increased awareness of the activities of humane organizations
24	Rudas *et al.* 1993	unspecified	hypermedia	increased teaching efficiency, decreased cost
25	Silva *et al.* 2003	surgery	cadavers	increased surgical skill
26	Simpson & Meuten 1992	clinical skills	pathology specimens	repeatability
27	Smeak *et al.* 1991	surgery	hemostasis model	superior surgical skill acquisition
28	Waldhalm & Bushby 1996	unspecified	personal computer	enhanced information retrieval and communication, improved student attitudes toward computers, increased employer perception of computer literacy.
29	Whithear *et al.* 1994	microbiology	hypermedia database	greater autonomy and more active learning, facilitation of postgraduate learning

use of animals within veterinary education are likely causes (De Boo & Knight, 2005 & 2006). These desensitization-related phenomena may represent psychological adaptations enabling students to withstand psychological stresses resulting from curricular requirements to harm sentient creatures, in the absence of overwhelming necessity (Capaldo, 2004). Consequently, the replacement of harmful animal use with humane teaching methods is likely to result in veterinarians with more positive attitudes toward animal welfare, which is likely to directly benefit their animal patients.

Conclusions

Sufficient studies have been conducted to draw some conclusions about the efficacy of humane teaching methods in imparting surgical skills or knowledge. Well designed humane alternatives generally perform at least as well as methods that rely on harmful animal use, in some cases achieving superior learning outcomes. These have included superior surgical, anesthetic and other clinical skill acquisition and development, superior understanding of complex biological processes, increased learning efficiency, and increased examination results. Additionally, increased teaching efficiency and decreased costs, along with enhanced potential for customization and repeatability of learning exercises, frequently result. Increased student confidence and satisfaction, enhanced preparedness for laboratories, and decreased student stress may also occur, as may enhanced student information retrieval and communication abilities, improved student attitudes towards computers, and increased employer perception of computer literacy. 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 may also result. Substantial numbers of animal lives are saved, and some evidence suggests that veterinarians trained without harmful animal use may develop higher animal welfare standards, potentially benefiting their future patients. They may also gain increased understanding of the pet overpopulation problem and the role of the veterinarian in combating it (Knight, 2007).

Rather than continuing to rely upon harmful animal use, the evidence clearly indicates that veterinary and other biomedical educators can best serve their students and animals, and can minimize financial and time burdens upon their faculties, by introducing well designed, humane teaching methodologies.

Detailed information about the alternatives available for various academic disciplines is provided by Jukes and Chiuia (2003) and at www.vetmed.ucdavis.edu/Animal_Alternatives 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 on-line computer simulations, comprehensive alternatives databases, academic reviews of leading alternatives, and hundreds of educational studies of alternatives organized by discipline, are also available at www.HumaneLearning.info and www.EURCA.org.

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