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Ethics and welfare of animals used in education: an overview

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Abstract

Ethical, regulatory and scientific issues arise from the use of animals in education, from secondary level schooling through to veterinary and medical training. A utilitarian cost–benefit analysis can be used to assess whether animals should be used in scientific education. The 'benefit' aspect of this analysis can be examined through comparative studies of learning outcomes from animal-based versus alternative training methods, while the 'cost', in terms of harms to the animals used, can be subject to technical assessment using Russell and Burch's (1959) 3Rs rationale. Science has only just begun to delineate the effects of educational exercises on the welfare of subject animals. It has also begun to develop technologies and modes of instruction that reduce, refine or replace animal use in education, and instances of their successful implementation in the UK and in the USA will be highlighted. The implementation of these alternatives to animal use is inconsistent, and barriers to the adoption of alternatives include specific curriculum and legislative requirements, traditional educational methodology, and resource and training limitations, particularly when the alternative methods involve new technologies. A further problem arises from the lack of existing research data comparing the educational value of alternative, with traditional animal-based, instruction methods. Greater consistency in the use of methods that reduce, refine or replace harmful animal use could be achieved through improved knowledge of the extent and type of alternative resources currently used in particular fields of scientific education; international comparisons of educational practice; close scrutiny and harmonisation of evaluation methods; and consistency in the ethical review of educational animal use. Information and training, both in the 3Rs and in the use of specific alternative methods, could be disseminated throughout the life sciences. Evaluative research of the educational efficacy of traditional animal-based methods versus refinements or replacements would provide high quality data on which to base decisions regarding teaching methods. Since educational exercises involving animals also impart ethical training, whether inadvertently or directly, instruction in applied ethics should be considered a key element of any education program involving animals.

Keywords: *alternatives, animal welfare, education, ethics, life science, student choice*

Introduction

An understanding of the biology and behaviour of animals forms the basis of animal welfare science and its practical applications aimed at maximising the welfare of animals in human care. However, the process by which students develop an understanding of the life sciences may, under some circumstances, cause harm to animals used as learning tools or biological models. This paper provides a brief overview of the rationale for the reduction, refinement or replacement (the '3Rs' [Russell & Burch 1959]) of harmful animal use in life science education, and of the methods by which this has been achieved. In so doing, it aims to highlight the benefits and limitations of reduction, refinement and replacement approaches both for animals and for students. Because educational animal use provides an important context for the development of attitudes to science, to the scientific use of animals, and to animals themselves, ethical discussions may be promoted by facilitated debate over animal use in the classroom and college. It is hoped that these discussions will promote further research and debate on an issue that may have important implications not only for animal welfare, but also for the teaching of ethics in science and for the development of future life scientists.

The context of animal use in biological science education

Animals are used in a wide range of instructional methods: from primary and secondary level school dissection exercises in basic life science education, through to undergraduate use in anatomical dissections, invasive physiological manipulations, animal behaviour studies in ethology and psychology, and as donors of animal tissue, for example for physiology and pharmacology exercises. Furthermore, animals are used in surgery and skills training for the veterinary and medical professions, as tools to develop skills related to biomedical research methodology, and in training for research animal and food production animal care (eg animal handling, invasive procedural techniques and disease management [Wolfenson & Lloyd 1998; Balcombe 2000]).

The use of animals in educational procedures has long proved a challenging issue for ethical, pedagogical, practical and ideological reasons. Perspectives across the life science professions are highly divergent. For example, strong support for animal-based protocols even at the most basic level of biological science education is evinced by the USA's National Association of Biology Teachers, whose 2003 animal use policy states: "No alternative can substitute for the actual experience of [animal] dissection or other use of animals and [the NABT] urges teachers to be aware of the limitations of alternatives." (http://www.nabt.org/sub/position_statements/animals.asp). In contrast, even at one of the highest levels of life science education — veterinary training — the use of animal-based instruction methods that lead to animal harm or death has been questioned. For example, Dr Lara Rasmussen, Director of Surgery and Clinical Skills at Western University College of Veterinary Medicine, USA, considers that: "instilling an appreciation of and propensity toward scientific thought are as important, if not much more important, to the maturing life-science learner, than knowing what a formalin-preserved kidney looks like and where it resides" (Rasmussen 2003).

Historically, animals were considered the only available means of transmitting certain kinds of scientific knowledge or practical skills, such as those related to physiological and pharmacological processes. However, with increased technological development, the use of 'alternative' instructional resources such as plastinated specimens, CD-ROM-based computer simulations, three-dimensional biological simulations and models has increased (van der Valk *et al* 1999; Jukes & Chiuia 2003). Furthermore, ethical concern for the wastage of individual animals has led to the development of alternative sources for the procurement of animals in cases where students' experience of invasive animal procedures are deemed essential, such as in veterinary training (see below). What is the basis for this change, and why are animal-based educational exercises of ethical concern?

Ethical issues concerning the educational use of animals

Moral issues are at the heart of the debate regarding animal use in education. Arguments centre on two distinct ethical themes. The first is based on rights/integrity theory and proposes that the value of animal life is such that animals should not be harmed or destroyed in educational activities. The second is a utilitarian (cost–benefit) perspective that balances the cost in terms of total animal suffering caused by an educational exercise against the benefit gained in terms of increasing scientific knowledge or practical skills for the benefit of human and animal health and well-being.

The first perspective reflects a moral concern for the destruction of animals, even if the exercise has no impact on animal welfare. This ethic emphasises the value of the life of the animal, often termed a 'reverence for life' approach (Francione & Charlton 1992, p 20), and proposes that learning within the life sciences should not be based on the destruction of animal life. The loss of life itself can be conceived of as an ultimate harm to the animal's integrity, ie to its 'completeness' (Regan 1985; Sapontzis 1987). In this sense, an animal which experiences a good life and an easy death may still be conceived of as having incurred a distinct harm by being used in the educational exercise. In operational terms, this perspective focuses on the replacement not only of directly harmful animal use, but also of other forms of animal use that may be otherwise benign but cause loss of life, such as the use of captive animals in behavioural observations which ultimately end in euthanasia. It does not rule out the study of animals; rather it requires that animals are not bred, manipulated or destroyed specifically for the educational exercise. For the study of dead animals, the loss of life should not be caused by the exercise or by the provision of the animal for the exercise. In its strongest form, provision of the animal should not be associated with other forms of destruction or damage to animal life, for example an animal organ should not be obtained from a slaughterhouse for an educational exercise. Furthermore, the study of live animals should not increase the risk of harm, injury or death to subject animals. The reverence for life perspective is often reflected in cases of student objection to animal-based science education exercises (Francione & Charlton 1992; http://www.animal-law.org).

The utilitarian approach presupposes that animals may be used in educational exercises; however, the benefit of performing the exercise in terms of human or animal health must outweigh the cost in terms of animal harm. In several countries, this ethical perspective is incorporated in legislation to determine whether animals should be used in scientific research practice and education: for example, the UK's 1986 Animals (Scientific Procedures) Act and the USA's Animal Welfare Act (for more information see Hart 1995; Rollin 1995). Adoption of the utilitarian approach has implications for the choice of instructional method: where more than one method is available, the method that maximises the benefit to harm ratio should be chosen. This process requires that existing alternative teaching methods be investigated and introduced into the curriculum, and emphasises the continuing need for the development of instructional methods and resources that limit animal harm. It also requires objective measurement of the harm that is caused to animals in educational exercises, and of the learning and performance outcomes of students, in order to determine the relative efficacy of different approaches.

Russell and Burch's (1959) 3Rs approach has been the basis for measuring and reducing the impact of particular procedures on subject animals. This approach proposes that priorities for the reduction, refinement or replacement of harmful animal use should be determined by considering the harmful impact of the procedure to be a function of the number of animals used and the extent of individual harm caused — the higher the number of animals, and/or the greater the individual harm, the greater the priority for change.

To determine the costs incurred by subject animals in existing educational practice and to identify priorities for the development of alternative instructional methods, data are required regarding the existing extent and type of animal use. For example, European Union (EU) statistics for 1999 reported that 1% of total animal use in scientific procedures occurred in educational and training exercises (Commission of the European Communities 2003). Within the EU, international reporting requirements vary. In the UK, it is

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possible to determine that the number of animals used in education and training procedures regulated under the Animals (Scientific Procedures) Act 1986 has declined from 8664 in 1987 to 5800 in 2001 (Commission of the European Communities 2003). However, other countries, such as Germany, have no legal requirement to maintain figures for animal use in educational exercises, thus it is difficult to determine trends in the use of animals or their replacements. Furthermore, under UK legislation, animals killed prior to the education exercise are not reportable, thus other forms of estimation must be used to measure these otherwise-invisible forms of animal use. For example, it is estimated that 30% of teachers in the UK, and 79% in the USA, use animals for high school dissection exercises (Croall 1994; ORC 1999; Balcombe 2000). In the USA, this amounts to an estimated six million animals per year with 49% of teachers reporting that they use foetal pigs and 73% reporting that they use frogs (Orlans 1993; King *et al* 2002). Prior studies have also suggested that the use of animal-based demonstrations and experimental exercises is inconsistent within some disciplines; for example, at the undergraduate level, a teaching methodology that is considered irreplaceable in one institution may not be utilised at all for the same learning outcome in another; however, supporting figures and rationale are not available (discussed in Pedersen 2002). To ensure consistency and best practice in the adoption of the 3Rs, there is a clear and urgent need for the accurate measurement of the prevalence and pedagogical rationale for animal use.

The type and extent of harms incurred by individual animals in educational exercises are as diverse as the exercises themselves and consequently cannot be comprehensively investigated here. Some key points arise, however, and these highlight a need for the assessment of animal welfare in relation to the breeding/rearing, acquisition, transportation, husbandry and killing of animals used for educational procedures, as well as for an assessment of the welfare implications of the procedures themselves. For example, the majority of the three million frogs supplied for dissection in the USA are wild-caught (Orlans 1993). Frogs are reportedly trapped, transported and held in large groups in sacks for several days, increasing the probability of injury, disease transfer and dehydration (reported in Balcombe 2000). Information on the methods used for killing frogs for school dissection exercises in the USA is unavailable, but it has been suggested that inhumane methods may have been used on occasions (Balcombe 2000). Humane methods for killing frogs are described by the AVMA (1993) and by Rhoades (2003). Foetal pigs used in school and college dissection classes in the USA are obtained from the food production industry as a by-product of sow slaughter (http://www.carolina.com/general/departments/dissection.asp). In this case, welfare assessment may extend beyond the subject animal to the animal from which it was obtained, requiring a calculation of the welfare of the sow to be taken into consideration.

In the USA, physiological and pharmacological manipulations used in college or undergraduate biology education can include invasive *in vivo* procedures (usually conducted under anaesthesia), such as the administration of physiologically active chemicals and the assessment of their effects on biological function. Invasive surgery will lead to the destruction of the animal. Welfare insult may be limited if the procedure is terminal and conducted under full anaesthesia, since the animal is thus not conscious of painful or distressing stimuli or procedures. Multiple survival surgeries, such as those used in some undergraduate experimental psychology and physiology classes in the USA, may have specific and particularly significant welfare implications because individuals are subjected to repeated invasive surgery and recovery (APA 1995; NRC 2003). The welfare impact of surgical techniques is dependent upon the quality of anaesthesia, analgesia and post-surgical infection management (Brown *et al* 1993). In experimental psychology and animal behaviour classes, learning/conditioning exercises that utilise pain or fear-inducing stimuli can cause animals distress, while neuropharmacological manipulations may cause emotional distress, for example through the application of anxiogenics (anxiety-increasing drugs) (APA 1995; NRC 2003).

The utilitarian cost–benefit calculation seems highly objective; however, the choice of currency of costs and benefits will be influenced by subjective factors such as the extent of personal concern for animal pain or distress, the perceived educational merit of particular methods, pedagogical and scientific ideology, and prior experience. It also presupposes that the costs and benefits are inherently measurable. Furthermore, the discussion relating to educational benefits must be essentially predictive, since the gain in terms of future scientific knowledge is dependent upon future numbers of students who utilise that knowledge in their careers. Not every student goes from a biological science degree into research; for example, less than 50% of pharmacology students enter a career directly related to their degree (Hughes *et al* 1997). Therefore, the benefit of the knowledge gained to future generations must be calculated to take into account the proportion of individuals who will utilise this knowledge, or an alternative approach introduced to predict, identify and provide appropriate training only to those students who will go on to use it.

One aspect in particular of the utilitarian calculus may be beneficial for assessing animal use in education: where an outcome in terms of the transmission of knowledge through traditional animal-based exercises is known, it may be possible to compare their effectiveness relative to novel, alternative methods. This process requires an explicit statement of the instructional goals of the exercise, along with valid, quantifiable and objective educational assessment techniques relevant to the skills and discipline being taught. The comparative assessment of educational techniques can provide an evidence base on which to decide between particular models and to determine the cost–benefit calculus more effectively. This approach goes some way towards clarifying the subjective element of decision-making regarding whether a particular technique is a suitable refinement or replacement model. Indeed, where refinement and replacement models are as effective as traditional animal studies, a utilitarian or cost–benefit analysis requires their adoption. The next section examines the basis for using animals in scientific education and briefly highlights some areas of educational animal use in which scientists and science educators have applied these approaches in order to successfully reduce animal harm.

Educational issues: what does the use of animals teach students about the life sciences?

Animals are used as models to demonstrate particular biological processes or structures and to examine the scientific process of discovery. These models fall into qualitatively distinct categories, such as:

• Models of basic biological processes or interactions, such as autonomic physiology.

• Models of 'higher' organisms for which manipulations would be ethically unacceptable.

• Archetypes of particular organisms or biological designs, sometimes for comparative purposes.

• Model subjects for the practise and development of experimental methodology and data collection and presentation.

• Substrates for the practise and development of physical/kinetic skills.

(For further discussion see Pedersen 2002.)

The aim of using these models is to impart a range of scientifically relevant information, including: the induction of new knowledge and the reinforcement of existing knowledge, the learning and practising of laboratory methods, data acquisition and handling, experimental design, communication, and teamwork (Dewhurst 1999, 2002). Their use may also impart skills in the care and maintenance of live animals or of preparations involving animal tissue, or in specific animal research-related methodologies, and they may serve as tools for the development of ethical judgment in relation to scientific practice (Dewhurst 1999, 2002).

The rationale for, and availability of, alternatives to the use of animals in science education is dependent upon the level at which education is directed. The following examples provide some indication of the types of novel approach that scientists have adopted to reduce, refine or replace animal use in education.

Applying the 3Rs in educational practice

1) Secondary level biology: the 'high school' dissection experience

Dissection continues to be a notable aspect of life science education at the secondary level and above in many countries including the USA and the UK (Balcombe 2000; King *et al* 2002). Authors have questioned the use of both vertebrate and invertebrate dissection in secondary level education, suggesting that it does not encourage deep learning of biological content, fosters rote learning, and is unnecessary for the effective teaching of scientific principles, while raising concerns that the process desensitises students to animal suffering and/or death (Orlans 1993, 1998). Others have suggested that the use of 'real' specimens encourages an enthusiasm for science and presents functional anatomy in a way otherwise impossible to simulate. However, there are many other means by which secondary level students can be exposed to highly motivating scientific experiences, and alternative exercises exist that provide equally effective teaching tools. For example, medical illustrators at the Medical College of Ohio, USA, have developed a range of highly detailed CD-ROMs for the teaching of human and comparative anatomy, using visualisations of real human and animal cadavers (http://www.mco.edu/cci/anatomy; http://www.prodissector.com). The 'Digital Frog 2' CD-ROM provides a learning tool in which interactive dissection simulations are incorporated with video clips and extensive modules linking functional anatomy to ecology (http://www.digitalfrog.com). Computer-based models such as the Digital Frog can replicate the interactive aspects of 'hands-on' learning methodologies in which the student learns by discovery, through both kinaesthetic and visual experience and by utilising problem-solving skills that enrich the learning process. Comparative studies suggest that students learn biological information at least equally well with simulated dissections as with animal-based exercises. For example, in a comparative study of simulated versus animal-based dissections, secondary level students performed equally well (Strauss & Kinzie 1994). Similarly, student performance was equally good following instruction via lectures and videos as via animal dissections (Fowler & Brosius 1968; Lieb 1985; McCollum 1987), and only one study using CD-ROM-based instruction found detrimental effects on student performance relative to the use of dissection (Matthews 1998). Some video dissections are of particularly high quality and include detailed narration of the dissection, such as those produced by the University of Portsmouth, UK, which are designed for undergraduate biologists (see http://www.eurca.org).

2) Undergraduate pharmacology, physiology and psychology

Both in the UK and in the USA, undergraduate level biological science education can include not only dissection, but also a range of *in vivo* exercises such as physiological manipulations of anaesthetised animals. In order to increase the extent of computer-assisted learning (CAL) and thereby reduce the number of animals used in such exercises in pharmacology courses, scientific educators at Leeds Metropolitan, Sheffield, and Edinburgh Universities in the UK have developed highly interactive computer programs which simulate a wide range of physiological exercises for use as direct replacements for laboratory exercises or as primers prior to experimental classes, thereby reducing the number of animals used (Dewhurst *et al* 1992, 1996; Dewhurst & Meehan 1993; Dewhurst & Jenkinson 1995; http://www.sheffbp.co.uk). These simulations can incorporate real experimental data or can be designed to reflect natural biological variation. Comparative analyses have shown that students using simulation software for pharmacological and physiological experiments gained equivalent results to those using dissections and animal-based laboratory experiments

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(More & Ralph 1992; Dewhurst *et al* 1994; Hughes 2001). CAL resources have thus proved valuable for the development of biological knowledge in these studies.

Undergraduate animal behaviour experiments can also be performed using simulations of operant and classical conditioning responses or by studying animals in their natural environment. For example, traditional operant conditioning paradigms can involve extensive periods of training of purpose-bred animals in the laboratory and sometimes involve the use of aversive stimuli. In one innovative experiment, undergraduate students studied an alternative operant conditioning paradigm using positive reinforcement on feral pigeons in a city park. These students gained equivalent scores on subsequent tests to students studying a traditional operant rat laboratory exercise (Cohen & Block 1991). It seems that a commitment to reducing, refining and replacing harmful animal use, and a little lateral thinking, may enable students to learn effectively without harming animals.

Are there cases where animal use is a necessary part of instruction? Clearly, where practical laboratory methodologies such as animal handling and anaesthesia are the central goal of the exercise, a hands-on approach may be required (Hughes 2001). However, there are simple means of ensuring that training causes minimal or no harm. Training in non-invasive laboratory animal care can utilise existing animals, removing the need for animals to be purpose-bred specifically for training purposes. A mentorship process, in which students or apprentice researchers work alongside skilled practitioners or investigators, would maximise the vocational validity of the training whilst again preventing animals being used solely as training tools (eg Rasmussen 2003). Simulations of invasive procedures are used for procedural learning in medical schools and this approach could be valuable to reduce or prevent harm in research training. The use of non-animal substrates for teaching suturing and similar skills is now practiced in veterinary and medical education, while the initial development of kinaesthetic skills can be modelled through the use of mannequins such as the 'koken rat' — a tool for training in intubation and injection (see Jukes & Chiuia 2003 for further details). One of the most interesting developments in non-harmful, yet animal-based curricula has arisen in veterinary education. Several veterinary schools in the USA, such as Texas A&M and Tufts University, now provide clinical experience of animal handling and physical assessment, plus training in surgery, using the animals of clients in a clinical setting as opposed to healthy animals acquired specifically for the exercise (Greenfield *et al* 1995; http://www.educationalmemorial.org). In this environment, gradual mentored exposure allows students to develop hands-on skills without risk to the client's animal. 'Educational Memorial Programs' provide an ethical source of cadavers for the practise of intubation, surgery and other invasive procedures, using animals that have died of illness or old age and have been donated consensually by their owners (Pavletic *et al* 1994; Kumar 2003; http://www.educational memorial.org). Veterinary students trained using these methods have been judged by their postgraduate employers to be equally capable in a wide range of animal handling, surgery and other veterinary techniques, demonstrating that the efficacy of veterinary education may not be compromised when utilising methods that replace the harmful use of animals (Pavletic *et al* 1994; Greenfield *et al* 1995).

Discussion

These examples indicate that the reduction, refinement and replacement of harmful animal use can be a practical reality in scientific education, from school level through to professional training. Furthermore, many of the alternative methods available are highly effective teaching tools. While in many cases, models and computer-based resources can achieve the same result in terms of the transmission of information and its retention by students, the number of studies comparing the educational merit of animal-based versus replacement teaching techniques is limited. There are also a number of considerations required when making these comparisons. For example, comparative evaluation presupposes that the learning goals of existing animal-based exercises are clearly defined; however, previous qualitative studies have questioned whether this is the case (van der Valk *et al* 1999; Dewhurst 2002). Caution should be exercised in extrapolating from existing comparative studies, since many are highly focused towards evaluating particular models using circumscribed measures of educational achievement (Dewhurst 1999; Pedersen 2002). It is essential that evaluations measure the types of knowledge or skill that are valid, not only to the instructional method, but also to the goals of the curriculum and to future employers such as research scientists and veterinarians (Greenfield *et al* 1995; Hughes 2001). There is a clear need for a greater amount and quality of evaluative research: 1) to assess the welfare of animals involved in educational exercises; 2) to examine where priorities lie, and how alternative biological models or teaching methods might best be adopted; and 3) to identify priorities for the development of alternatives where they currently do not exist.

Scientists have developed several resource and information services to disseminate knowledge and to encourage the adoption of non-harmful teaching methods. For example, the European Resource Centre for Alternatives in Higher Education (EURCA: http://www.eurca.org) and the Norwegian Inventory of Audiovisuals (NORINA: http://oslovet.veths.no/NORINA/) provide information on alternatives to animal use, including teacher evaluations of the relative strengths and instructional suitability of specific teaching resources and techniques. Interniche (http://www.interniche.org) has published 'From Guinea Pig to Computer Mouse', a comprehensive guide to humane teaching resources, which includes essays on curriculum design. In the USA, the Humane Society of the United States' (HSUS: http://www.hsus.org) teacher's consultancy assists educators to identify appropriate humane biology teaching resources, and its 'HELP' loan program allows teachers to trial resources. The triennial World Congress on

Alternatives to Animal Use in the Life Sciences (http://www.worldcongress.net) provides a scientific forum for debate on the use of animals in education and training, while Interniche's biennial conferences provide a link point for science educators and suppliers of alternative resources.

Structures for the prioritisation, development and evaluation of alternatives to harmful animal use in education are beginning to be developed, and as resources, infrastructure and awareness increase, so will the adoption of less harmful methods of teaching. However, there are already good examples of high quality educational techniques designed without recourse to harmful animal exercises, some of which have been discussed here, that are not necessarily widely replicated within academic disciplines or across international boundaries. Two mechanisms of information transmission and review would be valuable here. Firstly, further educational research comparing traditional animal-based methods with alternative instructional methods or resources would proliferate information and encourage debate on this issue. Research would be necessary not only to evaluate the effectiveness of alternative instructional methods, but also to identify their specific instructional goals and how these fit within the curriculum. Secondly, discussion and debate regarding the educational value of different instruction methods needs to increase within the particular academic disciplines for which students are being trained, so as to address the academic quality of instructional techniques, and to address priorities for study in terms of specific information and skills, and thus to advance scientific disciplines in concert with concern for animal welfare. The attitude that the reduction, refinement and replacement of harmful animal use in scientific procedures is a part of science, rather than being in conflict with it, has been increasingly embraced in research-related disciplines; this perspective should also be reflected at the educational level. The publication and dissemination of educational evaluations, including case studies, would increase the opportunity for ethical committees to make considered judgments regarding the use of animals within their institutions and thus would promulgate best practice in the use of non-harmful methods.

Where animal use regulations require the reporting of animal use in education, it is possible to identify priorities for refinement or replacement. However, much animal use, for example where dead animals are obtained for dissection exercises, may go unnoticed. To truly reflect the extent of the harm/cost involved in animal-based educational exercises it is essential that at least the number and the type of animals is recorded for all exercises that may involve animal harm. This practice might also elucidate otherwise-invisible instances where widespread reduction, refinement or replacement are feasible.

Prioritisation of efforts to reduce harmful animal use in education is also dependent upon developing an understanding of the effect of these exercises on animal welfare, in terms of the recognition, assessment, alleviation and prevention of pain and/or distress. Welfare scientists are well placed, in terms of their research skills and the availability of pre-existing study subjects within academic institutions, to objectively evaluate the costs incurred by animals involved in educational exercises.

Collaborative research between educational researchers and science educators would ensure that the highest quality evidence was obtained regarding instructional methods, while interdisciplinary efforts involving biologists, educators, statisticians, information technologists and engineers would allow the development of innovative teaching techniques and tools. Endorsing the concept of teaching without harm in the curriculum has been shown to benefit animals and to increase the accessibility of scientific disciplines to students, for example to those expressing a reverence for life philosophy (Francione & Charlton 1992; Birke 1995; Balcombe 2000). Animal welfare and a moral concern for animals have increasingly come to the fore in scientific disciplines (Rollin 1990; Appleby & Hughes 1997), and ethical discussions within animal-related curricula, from high school through to veterinary and research-related training, would equip students with the tools to critically evaluate their knowledge. Taking an evidence-based, morally aware approach, it may be possible to minimise animal harm whilst also ensuring that future scientists receive the best possible life science education.

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