Introduction
For a long time, animals have played an important role in education in the biomedical sciences. In particular in higher education, animals are used to teach anatomy, pharmacology, physiology and psychology. European statistics show that mainly fish and rodents are used. Most animals are being used in anatomy, physiology and pharmacology classes.

The tide seems to be changing. Because of economic reasons, public concern about animal use, and ethical issues we see an increased use of animal free models, and education seems less and less dependent on animals. In this review, a short discussion is given of the use of animals in education and availability and types of alternatives.

Animals in education
Despite the availability of a large number of alternatives (see later this review) a considerable number of animals are still being used in education. There still seems to be a belief that animals are essential to meet learning objectives. The clear definition of these learning objectives appears to be a very important (I. Hughes, 2000), but often neglected part within education. Why, what and how do we want to teach or train the students, how does it fit in the whole curriculum, is it appropriate and what is the best way to accomplish the learning objectives, are questions that are essential to be answered before every teaching activity is developed, but particularly when animals are involved.

Learning objectives given by teachers for laboratory classes involving animals may include (after (van der Valk et al., 1999):

- Learning and practising of laboratory skills including generic skills, animal handling skills, surgical/dissecting skills;
- Acquiring new and reinforcing existing factual knowledge;
- Learning and practising data-handling skills (taking measurements, recording, data presentation, analysis and interpretation skills);
- Learning and practising oral and written
communication skills;
- Developing responsible attitudes towards animal experimentation;
- Teaching methods of scientific research;
- Demonstrating the integration of complex systems;
- Demonstrating the dynamic processes of life.

After the definition of the objectives, the following questions need to be answered: (van der Valk et al., 1999):
- Are the teaching objectives of the experiment appropriate for the course?
- Are the teaching objectives of the experiment appropriate for the group of students?
- Are the teaching objectives of the experiment appropriate for all of the students in the group? (Over 50% of students in pharmacology do not enter a profession that require practical animal skills (I. Hughes, 2000))
- Is the use of animals the only way to achieve those teaching objectives?
- Is the use of animals the "best" way to achieve those objectives?

When all questions are answered positively, one view is that animal experimentation is only acceptable under the following conditions (van der Valk et al., 1999):
- animals are observed in their natural setting or during brief periods of captivity;
- animals are obtained from an ethical source, e.g. dissection of naturally died animals or those which have been euthanised;
- learning occurs in the clinical setting, where only animals in need of veterinary medical assistance are subjected to invasive procedures; or
- learning occurs by closely supervised apprenticeship in the research laboratory (specifically for students entering fields where they anticipate using laboratory animals).

More conditions and guidelines to consider, when planning or teaching education involving animals can be found in articles by Smith (Smith and Smith, 2004) and Balcombe (J. P. Balcombe, 2000).

From my experience as member on animal ethics committees, most animal classes are given because it “has always been done like this”. As soon as the whole curriculum is changed, or when a new lecturer takes over, it suddenly appears possible to change the tradition and learning goals in such a way that the animal classes are replaced by animal-free classes, without affecting the skills and learning of students. At some institutions it even seems possible to teach undergraduate students in biological sciences and students in veterinary sciences without animals (Rasmussen et al., 2003; Scroop, 2003).

International and national legislations (J. Balcombe, 2000), public concern and the increasing attention to the 3Rs (Replacement, reduction and refinement of animal experiments) require a more critical look at the use of experimental animals, in particular in education. Current standards dictate that animal use in education must be limited to an absolute minimum. The use of animals has to be directly related to the students’ future profession. Furthermore, when students are exposed to animal classes, they should be informed on the reasons why animals are used and about the ethical and legal aspects of animal experimentation. This way the course should contribute towards a proper attitude towards animals, based on the principles that animals deserve respect and have an intrinsic value. This attitude building should be part of the learning objectives. “The objective of attitude education is to teach the student to become aware of all aspects of his attitude, and be able to adapt it toward the well-being of the animal, within the demands of the context and the experiment” (Nab and Cappetti, 2000). A further opportunity to contribute to their attitude is through laboratory animal sciences courses. In several countries successful completion of this course is compulsory before scientists are allowed to develop animal experiments. The course should be based on FELASA recommendations (Nevalainen et al., 1999; Nevalainen et al., 2002).

In general, the laboratory animal science course covers (van der Valk and van Zutphen, 2004; van Zutphen and van der Valk, 1995):
- Biology and husbandry of laboratory animals;
- Genetic standardization and quality control;
- Gnotobiology and disease control;
- Animal models and experimental design;
- Experimental procedures;
- Anaesthesiology and analgesia;
- Animal alternatives;
• Ethics and animal welfare.
The entire course is focused on building an attitude that results in constant attention to the welfare of animals and application of 3Rs methods. Completion of the course gives authorisation to perform animal experiments, but we have to realise that the actual competence to perform animal experiments is only realised after further training on the job!

Alternatives to using animals in education
Over the years, several arguments have been raised to not use animals in classrooms: animal use has negative psychological effects on students and may lead to desensitisation (Capaldo, 2004) and to frustration due to unsuccessful experiments. Furthermore, these experiments may lead to large variation in results, are expensive both in money as in time from supervisors, may lead to animal suffering, animal experiments can only be offered once, etc. Moreover, national and international regulations (J. Balcombe, 2000) require the use of alternatives when these are available.

So, what are the alternatives? Existing alternatives can be classified as follows (based on: Jukes and Chiuia, 2003)
- 3D- Models, mannequins and mechanical simulators;
- Film and interactive video;
- Computer simulation and virtual reality;
- Self-experimentation and human studies;
- Plant experiments;
- Observational and field studies;
- Materials from slaughterhouses and fisheries;
- In vitro studies on cell lines;
- Dead animals from an animal-friendly and ethical source (e.g. naturally died and euthanised animals);
- Clinical practise.

A more extensive list of alternatives for different teaching procedures can be found in Hart et al., (2005).

Advantages of alternatives
Animal-free models have several advantages, dependent on the medium chosen. In particular, computer assisted learning (CAL) has become very popular over the years. Most of the current alternatives in education are computer-based. Advantages of alternative methods include (van der Valk et al., 1999):
- a specific animal experiment may only be offered once, whereas an alternative model may be used over and over again without constraints on time and place of study;
- alternative models can offer unambiguous and complete data and so avoid the negative learning experience of an ‘unsuccessful experiment’;
- an alternative may have built-in self-assessment to allow students to gauge whether staged learning objectives have been achieved;
- alternatives which make use of modern audio-visual techniques offer the possibility to demonstrate phenomena that are normally unobservable in the animal experiment, like animations of organ and cell functions, fly-throughs of organ systems, etc.

Clearly, alternatives offer several advantages, but do they really meet the learning objectives? Not many studies have been performed, but the ones that compared the learning results from students that were offered CAL to those who performed experiments on live animals and tissues showed equal or better performance of students using the alternatives.

Furthermore, it was shown that students who use the computer simulation acquired knowledge as well as students in the laboratory and that the primary learning objectives were equally well achieved (Dewhurst et al., 1994). Furthermore it was concluded that with CAL many learning objectives can be addressed, that there was increased student-staff interaction, that students are positive about the use of CAL and that the costs are lower than when using animals. In addition, a more recent study (I. E. Hughes, 2001) showed that the marks of students using simulations were significantly better than marks of students performing wet labs.

Introduction of alternatives
It appears that, although there is a wide range of alternatives available, there is still a limited use. The introduction and subsequent use of alternatives in education is not a straightforward activity for several reasons (van der Valk et al., 1999):
- some teachers are resistant to change and need convincing to use alternatives which are often developed elsewhere;
- integration of an alternative into a course will usually involve an initial investment of time and money;
• information about potential alternatives is not widely disseminated;
• the quality of the material available varies considerably; and
• there may be financial, technical and other factors which restrict the use of alternatives.

With respect to resistance of teachers the following anecdote may be of interest. Dr. Hans Braun, teacher in physiology was, initially, a strong believer that his learning goals could only be reached with animals. Yet, he reluctantly developed and introduced alternatives in his physiology teaching after strong student protest against animal teaching. He is now strongly supportive to the use of alternatives and his Sim series is very popular. His experience is that inexperienced students, who have to work on animal tissues, are very cautious not to damage the preparation and ask lots of assistance from their tutor. Although this careful approach contributes to the development of their attitude towards experimental animals, it appeared that computer simulations offered better opportunities to reach the initial learning goals. Computer simulations offer the student more possibilities to perform experiments, including those that would damage a live preparation and end the practical. Students work more independently with computer simulations, learn from their mistakes without loosing a live preparation, and gain better insight in the relationship between experimental setup and obtained results (Braun, 2003).

Some teachers argue that alternatives are not flexible, not developed in the local language, and not tailored to suit the specific need of the teacher. In some cases, though, developers of models offer help to tailor their products to specific needs. Moreover, in the near future, it will become possible to develop your own learning tool from different existing modules stored in a repository. Combining these modules in an order of the teachers’ choice with the possibility to include own items gives every teacher the opportunity to tailor a learning tool according to their own needs (Anon, 2006).

Sources of alternatives
As mentioned before, there are many types of alternative teaching methods developed, not involving animals. But how do you get informed about the availability and applicability of these models? The following sources can be consulted for information on alternatives (van der Valk et al., 1999)
• other teachers;
• from students who choose not to participate in animal experiments, and who find their own alternative exercises;
• by developing alternatives themselves, either alone or with others within their institutions;
• through conferences and trade fairs;
• through educational material marketing resources;
• from databases, e.g., NORINA, AVAR, eurca (see below);
• from outreach tours e.g., EuroNICHE, and publications;
• through loan programs from various institutions and organisations.

Relevant information web sources for alternatives
Nowadays, the easiest way to find information is to use the Internet. For alternatives in education, several Internet sources are available, of which the most important ones will be briefly discussed below.

InterNICHE http://www.interniche.org
InterNICHE stimulates the use of animal-free models by outreach tours, during which they demonstrate the value of alternatives, an extensive website with information on available alternatives, and a loan system that allows teachers students to borrow and try out different alternatives.

AVAR http://www.avar.org/
AVAR (Association of Veterinarians for Animal Rights) has an extensive database of alternatives (books, slides, computer models, etc.) for education to be used in primary schools to university education.

NORINA http://oslovet.veths.no/norina
The NORINA database is established by the Norwegian School of Veterinary Science and covers around 4000 animal-free models in education.

EURCA http://www.eurca.org
EURCA, the European Resource Centre for Alternatives in higher education offers a database with a limited number of items, but with extensive information on and reviews of the different models. Furthermore, eurca has a repository of alternatives which are regularly demonstrated at meetings.
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References


Capaldo, T. (2004). The psychological effects on students of using animals in ways that they see as ethically, morally or religiously wrong. Altern Lab Anim, 32(Suppl. 1), 525-531.


