Is Animal-Free Teaching in the Life Sciences Better Teaching?

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Summary

Animal use in university life sciences education and training is moderate compared to that for research, but it is still significant and often unnecessary for many students. Pharmacology practical classes involving experiments on whole animals or isolated organ/tissue systems use the most animals. A wide range of computer-based alternatives already exists, and there is good evidence that they can be both educationally and cost effective. The key to the usefulness of alternatives is the closeness of fit between the educational objectives of the animal experiments they will replace, the context in which the alternatives are to be used, and the design of the non-animal model. To further reduce animal use in education, it is important to convince faculty of the merits of alternative methods through awareness-raising, publishing evidence of successful use of non-animal methods in other universities, and providing assistance with integration of alternatives into mainstream teaching.

Keywords: computer-based alternatives, life sciences/pharmacology teaching, replacement alternatives in university teaching

1 Introduction

Over the time span 1989-2009, the use of animals in education has decreased sharply in the UK, from 12,000 or 0.37% of the total used for research to 1700 or 0.05%. Although this is encouraging, particularly when set against a steep increase in the number of life science students attending university, it is still significant. The numbers are also a gross underestimate, as current UK Home Office figures exclude animals humanely killed prior to tissue/organ removal for use in teaching. While a number of bio/medical/health and veterinary courses use animals, pharmacology courses, and to a lesser extent physiology and biochemistry, are the main users.

This same period has seen a significant trend towards using IT to enhance teaching and learning (e-learning), and this has included laboratory-based teaching using animals. Teachers now have access to a range of non-animal models designed to teach skills associated with laboratory practicals, including high quality computer simulations. The result is that a typical pharmacology degree course today is likely to contain far fewer laboratory practical classes using animals than a typical pre-1990 course.

The question arises whether it is realistic to reduce even further the amount of laboratory practical experience using animal preparations in university pharmacology courses while still preserving important course learning objectives and ensuring graduate employability.

2 The current situation – undergraduate pharmacology courses in the UK

Approximately fifty universities in the UK offer undergraduate courses in which pharmacology is a major component. About twenty are single honors BScs in Pharmacology, typically of three or four year's duration. Teaching is mixed mode and blends face-to-face (lectures, tutorials) and laboratory practicals with problem-based learning, student-centered learning – often using online resources and sometimes work placements – that provide additional laboratory training. There are also joint honors courses combining pharmacology with a related science such as physiology or sometimes a non-science subject such as management. In addition, pharmacology is an important component in other degree programs: medicine, veterinary medicine, pharmacy, dentistry, nursing/healthcare professional courses, and biological/biomedical sciences. Although there is wide variation from university to university, a single subject 3-year degree course in pharmacology typically will contain more than 700 hours of pharmacology teaching, with the majority being taught in years two and three of a 3-year Bachelor's degree course (Dewhurst and Page, 1998).

In 2004 the British Pharmacological Society (BPS) produced core curricula for the pharmacology content of a number of degree programs, recommending that all university courses with pharmacology in the title should provide education and training in:

- core concepts (e.g., absorption, distribution, biotransformation and excretion of drugs; source, nature, uses of drugs), and at least 50% of the 30+ drug areas (e.g., analgesics, antihypertensives)
- a range of laboratory skills
- a range of generic skills (e.g., communication, group-working, problem-solving)
- attitudes (e.g., working with animals in research, lifelong learning)

The BPS core curriculum for BSc Pharmacology courses recommends a minimum of 120 hours of laboratory-based practical work distributed through the course of the degree. More specific objectives should be taught as well, particularly in the final year of the course. These include practical experience of a range of isolated tissue experiments and whole animal preparations, cell culture methods, electrophysiology, ligand-binding, *in vivo* pharmacology, *in vitro* toxicology, immuno-pharmacological techniques, and animal handling. In contrast, the BPS core curricula for medicine, veterinary medicine, dentistry, professions allied to medicine and pharmacy makes no reference to the need for laboratory skills.

The aims of practical work may be defined as follows (modified from BPS core curriculum): to learn/develop/practice:

1. application of the scientific method and experimental design
2. problem-solving skills
3. generic biological practical skills (e.g., weighing, preparing solutions, pipetting)
4. skills in observation, measurement, appreciation of variability, concern for precision, data handling skills: analysis, presentation, and interpretation
5. oral and written communication skills: report writing, poster production
6. safety in the laboratory
7. pharmacology-specific practical skills
8. knowledge acquisition

A survey of the content of 18 UK BSc courses in pharmacology (Dewhurst and Page, 1998) showed significant variation from university to university, no clear core curriculum, and variable time spent in laboratory-based practical classes (mean 42 h ±10 S.E.; range 0-145 h). Typically students also would develop practical skills in final-year projects on which they spent considerable time (mean 216 h ±31 S.E.; range 0 (library-based dissertation) – 454 h).

3 Employability

Pursuit of a research career in academia or the pharmaceutical industry is a major reason for ensuring that pharmacology graduates acquire laboratory skills during their university degree. A survey of 52 UK universities identified the employment of pharmacology graduates (705 BSc, 36 MSc, and 96 PhD) six months after graduation. The proportion of students undertaking further training was 36% (BSc), 34% (MSc), and 4% (PhD). Employment that required pharmacological knowledge was undertaken by 18% (BSc), 18% (MSc), and 67% (PhD). Graduates going into non-pharmacological employment were 18% (BSc), 3% (MSc), and 2% (PhD). The remaining graduates had either gone abroad, were unplaced and seeking/not seeking employment, or of unknown employment status. The authors concluded that a significant proportion of pharmacology graduates made use of their pharmacological education or embarked on further training, though only 11% gained employment in the pharmaceutical industry in contrast to >90% in the 1970s (Hughes, 2002).

Strange (2005), reported that students are not being adequately trained in integrative pharmacology, and the number of senior scientists able to provide such training in this area is diminishing, largely as a result of the shift in focus of biological research to a more reductionist approach. This decline, as well as a global shortage of experts in the field, has happened at the same time as a marked decrease in the production of new, safe, and efficacious drugs (Collis, 2006; Shankley et al., 2006). There are now a number of initiatives to ensure that more pharmacology graduates receive adequate training in laboratory skills and *in vivo* techniques.

4 Non-animal models in life sciences teaching

A number of non-animal models exist (see review by Gruber and Dewhurst, 2004) and are available to teachers: computer simulations in pharmacology and physiology; video/interactive video for teaching anatomy; manikins/models/simulators/virtual reality to teach clinical or low level surgical skills; human self-experimentation, particularly in physiology where students perform experiments on themselves or fellow students; plant, post-mortem, and cultured cells/tissues. A number of other approaches also are used to reduce animal use, such as: ethically sourced cadavers and supervised clinical practice, particularly in veterinary medicine, as well as tutor-led demonstrations where experiments are performed on only one preparation used to teach the whole class rather than use an animal/animal preparation for each individual student.

Computer simulations (virtual laboratories), the main focus of this paper, probably have had the greatest impact on animal use in pharmacology education (Gruber and Dewhurst, 2004) and can be divided broadly into:

a) *Simulations of preparations* – use predictive algorithms to generate simulated tissue responses in response to user-selected variables. They are extremely flexible in how they can be used, giving the user control over experimental parameters such as: which drug (either alone or in combination with an antagonist/potentiator); drug concentration; and electrical stimulation parameters. Once these decisions have been made, the student is presented with a tissue response (e.g., contraction of a length of intestine) generated from an algorithm, often derived from data of previous animal experiments.
b) *Simulations of experiments* – use "real" data collected from previous experiments to reproduce simulated tissue responses. Students are presented with data from a defined series of experiments designed by a tutor to ensure primary learning objectives are achieved and experiments are relevant. They often are designed for learning independent of tutor support and typically have built-in assignments and activities and provide on-screen support, such as background information and self-assessments. Drug concentrations are normally pre-determined to be optimal for that particular drug, and only selected antagonists/potentiators are available. Not as flexible for designing experiments, but students do not waste time trying out inappropriate drug concentrations, drug combinations, or electrical stimulus parameters.

5 Using non-animal models – computer simulations

Computer simulations frequently are used as direct replacements for animal labs. Students work in small groups of two or three (as they would in the real laboratory) and follow a tutor-designed schedule, gathering data from the computer screen in much the same way as they would from conventional data recording equipment such as a chart recorder. Some programs include an "unknown" drug, and students may be required to design experiments to determine what class of drug the unknown is.

Typically they would be required to complete learning activities that may include multiple choice/true-false questions to test factual knowledge, as well as data analysis and data interpretation exercises. They may be asked to write a report of the simulated experiments, write an abstract, create a group presentation of their findings, or deliver a poster or oral communication.

Even where students are required to take part in animal labs, computer simulations may reduce the number of animals needed by allowing students to better design appropriate experiments and determine appropriate dosages in the virtual lab before they use an animal. Virtual labs also may be used for debriefing students in a face-to-face tutorial situation, as a fallback for students whose animal experiment "fails," and to enable students to collect data additional to what they collect from the animal preparation, as frequently preparations will deteriorate before students are able to complete all of the experiments.

6 Teaching and learning objectives

A number of studies (see Knight, 2007 for review) provide evidence that computer-based alternatives can address some of the learning objectives of animal labs. For example, knowledge acquisition and skills such as data handling, experimental design, communication, and team working may be achieved as well, if not better, than with animal labs. In addition, the virtual labs also promote interactive, resource-based learning and the development of IT skills.

Computer simulations are not useful in teaching generic laboratory skills (e.g., making up solutions, weighing, titrating), setting-up and using equipment, or more specific pharmacology skills such as animal handling, anesthetization, surgery, administering drugs, monitoring physiological signs, and humane killing at the end of the experiment. These latter skills, at the moment, truly can only be taught through animal experiments, although videos, simulators, virtual reality and haptics technology can be used to practice some of these skills and better prepare students.

7 Using alternatives effectively

The impact that alternatives will have on animal use depends on the closeness of fit of the alternative with the needs of the institution and the willingness of faculty in that institution to integrate them into mainstream teaching. Where alternatives have been developed by teachers for their own use they are usually well integrated and work well in achieving the learning objectives for which they were designed. However, the situation is sometimes quite different when these programs are made available to other teachers who are often resistant to using resources developed elsewhere, particularly if using that "alternative" requires more time and effort than continuing to use the animal lab. Resources are required to successfully integrate a new method into the curriculum (e.g., develop support materials for), and often faculty lack the time and sometimes the skills to do this. Sometimes this means they rely on simply making the alternatives available to students to use independent of tutor support, an approach that does not work (Markham et al., 1998).

The evidence is that using computer simulations requires a similar tutor-supported learning environment to that of the "real" laboratory class. Local development of such support materials as workbooks or study guides gives direction to the class and allows faculty to take some ownership of the educational process. The support materials may be similar to a laboratory schedule containing learning objectives, tasks, exercises, and assessments. A project in the UK demonstrated that providing pharmacology teachers with a set of exemplar support materials (consisting of workbooks, self-assessment activities, case-based and problem-based learning scenarios) helped faculty to integrate computer-based resources into their teaching (Norris and Dewhurst, 2002).

8 Conclusions

1. Existing (computer-based) alternatives can meet the learning objectives for many university students studying pharmacology and/or physiology in a variety of courses in which these are major components, and there is good evidence of the educational efficacy of such alternatives from numerous evaluative studies.
2. More could be done to persuade faculty to switch from unnecessary use of animals in teaching to alternatives, and the evidence is that they are most convinced by independent review of different evidence of educational efficacy and by recommendations from (trusted) colleagues.
3. Integration of new teaching methods into the curriculum is often time-consuming and, for some faculty, quite difficult. Provision of help in the form of exemplars or good practice guides to support a move from animal-based teaching to non-animal methods has proved to be successful.
4. Some skills, including training in *in vivo* methods, are required to pursue a career in (animal-based) research in, for example, the pharmaceutical industry or academia, and there is a recognition that, in some countries, education systems are failing to produce graduates with these skills and that this might adversely affect science industries.
5. At the moment, there are no realistic alternatives to using animals for *in vivo* skills training, and these are the skills

required by (a small number of) pharmacology/life sciences graduates wishing to pursue animal-based research careers in the pharmaceutical industry or academia.

6. Whether it is necessary to use animals in undergraduate (Bachelor's) education, or whether training in such skills would be more appropriate at the postgraduate level, is questionable. If it is to continue at the undergraduate level, then it is important that animals are not used unnecessarily to train students who will not pursue research careers.

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