Computer-based Alternatives to Using Animals in Teaching Physiology and Pharmacology to Undergraduate Students

David Dewhurst

Learning Technology Section, College of Medicine & Veterinary Medicine, University of Edinburgh, Hugh Robson Link Building, 15 George Square, Edinburgh EH8 9XD, UK
E-mail: *d.dewhurst@ed.ac.uk*

Summary — In the UK, the majority of animals used for undergraduate education are for laboratory practical classes (wet labs) in pharmacology and physiology. Computer simulations, which are now widely available at relatively low cost, can provide a dry lab experience that may fulfil some, but not all, of the objectives of the animal labs and may be particularly appropriate where the animal lab is costly to run or requires a high level of technical expertise. Broadly, the computer simulations fall into two categories, each having design features in line with achieving slightly different learning objectives. Most of the available evidence suggests that where computer simulations are used as alternatives, they can fulfil many of the learning objectives of wet labs, though clearly they are not effective in teaching animal handling, surgical/dissection and laboratory skills.

Key words: *alternatives, computer simulations, undergraduate pharmacology teaching.*

Introduction

Reported animal use for teaching across Europe varies from country to country, but is small (< 2%) relative to the total used for research, and this number is declining, even against a background of significantly increased student numbers. However, it still represents a significant number of animals. For example, in the UK, Home Office figures for 2000 show that 4680 animals, i.e. < 0.2%, were used for educational purposes out of a total of 2,714,726 animals used for all purposes, including research (1). Most are small rodents or amphibians, and disciplines such as pharmacology and physiology are the primary users. This figure is also a gross underestimate, as animals that are killed just prior to use would not be counted in the UK figures. Thus, isolated tissue preparations from freshly killed animals, which form the mainstay of pharmacology practical teaching, would not be counted in the official figures.

Over the last 15 years or so, numerous computer-based alternatives to using animals in teaching these disciplines have been developed and are widely available at relatively low cost. Although there is little direct evidence, it is likely that the availability of realistic alternatives has made a significant contribution to this reduction in animal use for educational purposes. Wet labs are expensive to run, and the pedagogical shift away from didactic to student-centred, resource-based learning has meant that most higher education courses are under pressure to reduce staff–student contact hours. In many cases, course organisers have had to reappraise the learning outcomes of their courses, and as a consequence, they have realised that many of the learning objectives of wet labs can be equally well achieved, using dry lab alternatives, which are also less costly.

Discussion

Computer simulations as alternatives to wet labs, which traditionally use animals or animal tissue

Broadly, computer simulations of lab practical classes (wet labs) in physiology and pharmacology may be divided into two categories:

Simulations of preparations

These use predictive algorithms to generate simulated tissue responses in response to the user selecting certain variables. They are extremely flexible in how they can be used, giving the user control over experimental parameters such as: which drug to add to a tissue bath; what concentration of the drug; whether the drug is added alone or in the presence of an antagonist or potentiator; whether the tissue is electrically stimulated (perhaps to release endogenous substances); what electrical stimulation parameters are used. Thus, they may present the student with a "virtual" pharmacological preparation, such as a cat anterior tibialis-sciatic nerve preparation *in vivo,* where the animal is anaesthetised and set up such that electrical stimuli can be delivered to the sciatic nerve and contractions of the tibialis anterior muscle can be recorded. This preparation can be used to teach students the pharmacology of neuromuscular transmission and the characteristics of depolarising and non-depolarising neuromuscular blocking agents. In the real and virtual preparation, pharmacological agents can be administered by intravenous injection either alone or in combination with antagonists or potentiators. Students can choose a drug from an extensive list, the concentration at which it should be administered and whether to add the test drug alone or in combination with an antagonist (again, they will have a choice of a number of potential antagonists and concentrations at which they may be administered). Once these decisions have been made, the student is presented with a tissue response (contraction of the tibialis anterior muscle if the chosen parameters of the experiment are suitable), which is generated from an algorithm, the development of which is based on data from previous experiments using this tissue.

Computer simulations of this type require significant tutor support to be useful. Tasks must be set for a worthwhile learning experience to be achieved. These tasks may be fairly prescriptive, e.g. administer drug X at a dose of Amg/kg; observe the pattern of muscular contractions until they have returned to control levels; repeat the experiment with drug Y at a dose of Bmg/kg; repeat again, administering drug Y (Bmg/kg) 5 minutes before drug X (Amg/kg); observe the effects of drug Y alone and compare the effects of drug X alone and after prior administration of drug Y. Or, the tasks may be more open-ended, e.g. design a range of experiments to identify the class of drugs represented by unknown drug U. This type of program is, perhaps, most appropriate to better prepare students who will later perform the live experiment, e.g. students can do a "dry run" to try out drug doses, stimulation protocols, plan experiments and so forth. Alternatively, they allow students who have already performed a limited range of experiments using the live preparation, or who have seen it only as a tutor demonstration, to collect data from a greater range of experiments than the live experiment permitted. Similarly, the simulation may act as a fallback, providing data for students whose experiments were not successful.

Simulations of experiments

Here "real" data, collected from previous experiments, are used to reproduce simulated tissue responses. The focus is to present students with representative data from a defined series of experiments that have been designed by a tutor to ensure primary learning objectives are achieved and experiments are relevant. These programs are more akin to a virtual tutor-led demonstration, where students collect the data from the monitor as they would from whatever output device was used in the "live" experiment. The programs are often designed to offer a replacement for a laboratory session, suitable for learning independent of tutor support, under circumstances where the "live" experiment cannot be performed, e.g. high cost of an animal laboratory (such as the traditional dog lab for teaching cardiovascular function), or lack of specialist equipment or technical expertise. They often have built-in assignments and activities and provide on-screen support, such as background information and self-assessment activities. This type of program might also be used as an alternative to a cat anterior tibialis-sciatic nerve practical and, in fact, takes an approach to supporting learning similar to that employed by a tutor who prepares a worksheet or schedule for students to follow in the laboratory. Thus, the program would comprise a series of clearly defined experiments, each designed by an experienced tutor, to enable students to meet specific learning objectives that can be achieved using that preparation. Drug concentrations would be pre-determined to be optimal for that particular drug, and only selected antagonists or potentiators would be available. Students would not have the same degree of flexibility in designing experiments, but neither would they waste significant time trying out drug concentrations, drug combinations or electrical stimulus parameters that were inappropriate.

Which learning objectives can computer simulations achieve?

To answer this question it is important to define the learning objectives of laboratory-based practical classes. These will undoubtedly differ from university to university, from tutor to tutor and from practical to practical. However, they may include: providing a vehicle for students to learn and practise skills (specific and generic practical skills; data collection; data handling; data interpretation; report writing and communication; group working); teaching new and reinforcing existing knowledge; promoting active learning; and facilitating lecturer–student contact.

Computer-based simulations can achieve some of these at least as well as, and in some cases, better than, traditional practical classes, where the achievement of learning objectives is sometimes obscured by technical problems, unfamiliarity with equipment, and preparations becoming rapidly non-viable. The simulations provide good quality data (reasonable biological variation can be programmed in), which are not "blurred" by deterioration of the preparation through fatigue, anoxia, mishandling, or the like. These data can be used to practise data collection and handling skills, experimental design skills, scientific communication skills (report writing, oral communication, poster production). Also, if the dry lab is run with a tutor present, students can be directed to work in groups to address specific learning goals, and staff–student interaction will be promoted.

However, it should be remembered that certain skills cannot be taught by using computer simulations, e.g. teaching laboratory skills, animal handling skills, raising awareness of ethical considerations in using animals and the art of "doing" experiments. For many students, probably a majority, these latter learning objectives may not be important. For example, for medical, dental, healthcare, and many biomedical science students, these skills are not primary objectives, and it is a minority (those who wish to pursue a career in research) for whom they are important. Tutors must decide the primary objectives for the students they teach and, if these include skills that cannot be addressed by computer simulations, then, there is probably no substitute for animal experiments.

There are other major advantages of using computer-assisted learning programs. The high quality of presentation of factual information is often well beyond that of a typical lecture or textbook, e.g. animations, and high quality graphics may be incorporated. The level of presentation is consistent, and access to the resource by the user is flexible — students can work when it is convenient to them, and at their own pace.

Are computer simulations effective in achieving learning objectives of wet labs?

The evidence from a number of studies is that they are, but it depends on what the learning objectives are and how success is evaluated.

Two studies (2, 3) compared the laboratory report marks of different cohorts of undergraduate students. The control cohort performed a frog experiment (isolated sciatic nerve preparation) in the laboratory, and the test cohort used a computer simulation of the same experiment. Both studies found no statistically significant difference in the marks for the laboratory report, the standard form of assessment for a wet lab.

Another study (4) compared a specific computer simulation program (simulating experiments to measure intestinal transport of nutrients) with a laboratory-based mini project using the isolated, everted intestinal sac of the rat preparation within a single cohort of undergraduate students in one UK university. They found that: knowledge gain of the two groups was equivalent (based on a pre- and post-knowledge test); students who used the computer-based alternative to the animal experiment became more positive about the learning experience after they had used it; and the cost of running the computer-based session was significantly lower than that for the laboratory session (the computer program was used with a printed workbook with no tutor support, whereas the laboratory-based project required full tutor support and some technical support). Clearly, the two groups achieved different objectives, but interestingly, the tutors who ran this teaching session did not identify the laboratory/animal skills as being primary learning objectives.

A more recent study (5) compared the academic performance of students doing wet practicals (where students set up and manipulated their own tissue preparations, prepared their own solutions and calculated and prepared the doses and concentrations to be used as specified in the exercise schedule) with those who used a computer-based simulation. Academic performance was assessed by a write-up that measured theoretical knowledge of the practical. The study demonstrated that, in each of five separate studies, the assessed performance of the students who did the simulated experiment was statistically significantly better than that of the students who did the wet practical. However, there was some evidence that some weeks later the wet practical group was that better able to recall the practical details of the experiment they had performed.

Several other studies (6–9) have also demonstrated the effectiveness of computer-based alternatives compared to the traditional approach using animals

Conclusion

A broad range of computer simulations of traditional animal labs in pharmacology and physiology teaching are now widely available at relatively low cost. The evidence from a number of evaluative studies is that the dry lab experience that the simulations provide may fulfil some, but not all, of the objectives of the animal labs. They are effective in reinforcing existing knowledge, in teaching and practising skills such as experimental design, data handling, data interpretation, oral and written communication and in promoting group work. Clearly, they are not effective in teaching animal handling, surgical/dissection and laboratory skills, and where these are judged to be important learning goals, there is no substitute for the animal lab. However, many students, probably a majority, for whom pharmacology and physiology are important components of their course, can learn the pharmacology they need for their future careers as effectively by using computer simulations.

References

1. Home Office (2001). *Statistics of Scientific Procedures on Living Animals. Great Britain 2000.* London, UK: HMSO.

2. Clarke, K.A. (1987). The use of microcomputer simulations in undergraduate neurophysiology experiments. *ATLA* **14**, 134–140.
3. Dewhurst, D. G., Brown, G.J. & Meehan, A.S. (1988). Microcomputer simulations of laboratory experiments in physiology. *ATLA* **15**, 280–289.
4. Dewhurst, D.G., Hardcastle, J., Hardcastle, P.T. & Stuart, E. (1994). Comparison of a computer simulation program with a traditional laboratory practical class for teaching the principles of intestinal absorption. *American Journal of Physiology* **267**, S95–104 (*Advances in Physiology Education* **12**).
5. Hughes, I.E. (2001). Laboratory practicals in pharmacology teaching — do they meet the learning needs? *Trends in Pharmacological Sciences* **22**, 71–74.
6. Fawver, A.L., Branch, C.E., Trentham, L., Robertson, B.T. & Beckett, S.D. (1990). A comparison of interactive videodisc instruction with live animal laboratories. *American Journal of Physiology* **259**, S11–14 (*Advances in Physiology Education* **4**).
7. Guy, J.F. & Frisby, A.J. (1992). Using interactive videodiscs to teach gross anatomy to undergraduates at The Ohio State University. *Academic Medicine* **67**, 132–133.
8. Kinzie, M.B., Strauss, R. & Foss, J. (1993). The effects of an interactive simulation on the performance and achievement of high school biology students. *Journal of Research in Science Teaching* **30**, 989–1000.
9. Leathard, H.L. & Dewhurst, D.G. (1995). Comparison of the cost-effectiveness of a computer assisted learning program with a tutored demonstration to teach intestinal motility to medical students. *Association for Learning Technology Journal* **3**, 118–125.