

IT in teaching experimental science: the scientific perspective

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Introduction

Experimental investigation provides the foundation of science. Theoretical models describing the natural world result generally from practical observation of phenomena. Thus it is important that our students, who will be the next generation of scientists, understand the experimental basis of the “facts” in their textbooks, and gain experience in the practical side of scientific investigation. Therefore, it has traditionally been considered important that training scientists are exposed to ‘wet’ laboratory sessions. An extension of this approach is that replacement of practicals with other activities devalues a practical course. However, this view must be tempered by other important factors.

One needs to consider the orientation and perspectives of different groups of students, and the appropriateness of their practical experience. Taking an example from my own field of biochemistry, there are some groups of students for whom ‘wet’ practical work is not highly appropriate (Learmonth *et al.* 1988). For example, students of medicine and nursing do not need to develop biochemistry laboratory skills, but rather gain an understanding of the experimental basis and interpretation of clinical test data. In some medical courses biochemistry practical work has been replaced altogether by other activities such as clinical case problem solving (Scott and Shanley 1988).

In contrast, for students studying the experimental sciences in their own, ‘wet’ practicals are critical to the learning experience. Nevertheless, the question must be asked whether a traditional laboratory course meets the needs of our students. There are commonly significant limitations in that it is not possible to expose students to all of the vast array of techniques and scientific equipment, nor in many cases provide sufficient repetition for students to gain mastery of a technique. We are generally capable of providing tuition in a selection of techniques and approaches, and hopefully impart the culture of scientific investigation and encourage the ability to adapt and operate in diverse environments. Thus we cannot fulfil all our objectives with ‘wet’ practicals alone. There is much to be gained from stepping back and looking at ‘dry’ lab activities, which can supplement and enhance the ‘wet’ lab experience. One needs to identify where computers can be effectively applied to extend and enrich the curriculum, and how the computer-based activities can be integrated into learning experiences in non-trivial and meaningful ways. The same questions should be asked of ‘dry’ and ‘wet’ activities, in summary whether they meet the objectives. Further, do the students, and for that matter the instructors, have a clear idea what the objectives are? Objectives of practical classes have been summarised by Bender (1986).

Key elements of computer-based ‘dry’ laboratories

There are a number of issues to be considered in the implementation of ‘dry’ laboratory sessions in a practical course. Foremost amongst these are questions of intellectual appropriateness of individual exercises, and teaching efficiency and effectiveness. Logistical considerations also need to be addressed, including availability and location of computer laboratories. Often the major driving force for implementation of ‘dry’ labs is reducing the expenses in terms of laboratory consumables and staff time. However if materials are to be developed in-house it must be recognised that establishment costs will be high. Key elements of successful computer aided learning include the software, the instructors and the learners.

Software considerations include validity, appropriateness, ease of use, flexibility and quality. Validity for example of the theoretical model or database used in a simulation program should be confirmed. It should be asked whether it is appropriate or better to present the material by computer or via another medium. A program should show flexibility in its design, including variation of data or sequence so users do not become bored, preferentially with different levels of complexity or challenge and providing user control over sequence of activities or variables in a simulation. The software should also be easy to use and robust.

Instructor-related factors include attitude, selectivity and integration. It is important that all instructors are comfortable with the technology and confident and skilled in its use. Both positive and negative attitudes influence student perception of the value of an exercise, which will affect learning outcomes. It is important to apply selectivity in the choice of appropriate software, and that the computer-based activities are truly integrated into the course.

Learner-related factors include attitude, engagement and preparedness. Students’ attitudes are often related to the instructor’s attitude, but also reflect their confidence in using the system, prior computer awareness and knowledge, preparation for the exercise and perception of its value. Engagement is a reflection of commitment, and may be evidenced by total time spent on the activity or enjoyment. Engagement is necessary, but not sufficient to ensure a positive learning outcome. User control and feedback on progress seem to be major contributors to keeping interest. Cognitive preparedness is also important and relates to integration of the activities.

Other important factors include the number of students per workstation, the setting and the formality of the activity. I have generally found that it is better to have 2-3 students working together. To proceed they must discuss steps or actions to take and reach agreement on theoretical points and concepts. The setting can be important for integration of computer-based activities, for example it seems to be better to have computers available in or near the regular class location, as opposed to a central facility distant from the normal work environment. Formality of classes can also be important, for example formal classes provide strong temporal and contextual links between computer-based and other learning activities. However this is often constrained by the number of students and time available, often meaning that students must cycle through the computer-based and other integrated activities. The activities may also have to be pursued out of class hours.

Types of computer-based activities

There is a great potential for computer-based exercises to supplement and extend practical experience, provided they are truly integrated with the other activities in a course. Such exercises fall into a number of categories including those that assist students in preparation for ‘wet’ laboratory work and those that extend the course by providing practice

in data analysis or simulating data from equipment not available, or techniques too difficult for students to master within the constraints of the timetable. A variety of alternative exercises have been developed over the years to supplement practical classes. Many of these are not computer-based, for example “pen and paper” calculations assignments and activities designed around textbooks, lecture notes, diagrams and “feelware” such as molecular or anatomical models. Such resources have been around for a long time and some are now being used successfully as adjuncts to computer based material. The discussion here will be limited to computer-based applications, outlined in various categories below. Specific examples will be discussed in the paper for the workshop “Dry Labs in Biochemistry Departments”.

Assistance with ‘pre-prac’ preparation

Lack of preparedness of students and the danger of becoming engrossed in technical and logistic aspects have been identified as major problems in biochemistry practical classes (Parslow 1993). Computer-based simulations of experiments have been applied to assist students prepare for biochemistry practical work (Learmonth 1994). This helps students to become familiar with the conceptual, logistical and numerical aspects of a practical before coming to the laboratory. Programs have also been developed to simulate the operation of specific items of equipment such as spectrophotometers, HPLC or NMR equipment. These may be used prior to practical classes to provide background and training in equipment that students will use. In some cases they may provide simulated use for data collection from equipment that is not available for student use.

Assistance with data manipulation and calculations

Computer programs have been devised to assist in laboratory calculations (*e.g.*, Carrington 1993; Wiseman *et al.* 1995) or to assist in analysis of data obtained at the bench (*e.g.*, Jones *et al.* 1985; Pamula *et al.* 1995). These programs variously find application before, during or after practical classes. The emphasis of these types of program is on the correct processing and analysis of data. This should enhance the understanding and interpretation of the data obtained either at the bench or by computer simulation. Such programs may also assist students in their drawing of valid inferences and conclusions from their data.

Simulated data acquisition

Examples include combined ‘wet’ practical/data simulation, which may be to extend analysis to areas that cannot be covered in a practical session (*e.g.*, Bender 1986). Another approach is to simulate experimental data that must be recorded in traditional fashion, possibly providing further assistance in analysis of the simulated data (*e.g.*, Jenkins and Cartledge 1995). A third approach is to simulate the entire experiment (*e.g.*, Day *et al.* 1996; Fyfe and Fyfe 1996) or a process such as purification of a protein (Booth 1987). Applications of computer simulations in biochemistry have been reviewed previously (Learmonth 1991).

Summary and Conclusions

A combination of ‘dry’ and ‘wet’ laboratory activities can be used effectively to separately address important facets such as obtaining results, data manipulation and formulation of conclusions from the data. Often the focus of ‘wet’ practicals is on obtaining experimental data, which may be of dubious quality. ‘Dry’ activities can be used to teach

problem solving and data manipulation using “good” data. Practice in data handling and calculations will stand students in good stead when subsequently performing “real” experiments, as can simulation activities designed for training equipment use, or simulation of processes. If we can assist in preparation of students for practicals, then we can make the whole experience more valuable. Furthermore we may also be able to open up a window of opportunity by simulating experiments not practicable in existing courses.

The use of computer-based activities may not guarantee learning, although the question may be asked whether anything can provide such a guarantee. However it seems likely that the power and flexibility of computers combined with speed and ease of use for simulation and analysis of experimental data may take some pressure from the learner and potentially promote engagement and motivation. The latter is perhaps the most important aspect of learning. The bottom line is that the quality of the learning experience will largely determine the quality of our graduates and their ability to adapt and operate as professional scientists.

References

- Bender, D.A. (1986) Combining a laboratory practical class with a computer simulation: studies on the synthesis of urea in isolated hepatocytes. *Biochem. Educ.* **14**, 17-22.
- Booth, A.G. (1987) Protein Purification. IRL Press at Oxford University Press.
- Carrington, J.M. (1993) An evaluation of computer-aided instruction program on laboratory techniques and calculations. *Biochem. Educ.* **21**, 29-31
- Day, D., Arundel, M. and Bennett, S. (1996) Oxidative Phosphorylation. A simulated experiment. *UniServe•Science News* **3**, 15.
- Fyfe, S. and Fyfe, G. (1996) The osmosis program. *UniServe•Science News* **3**, 16.
- Jenkins, R.O. and Cartledge, T.G. (1995) Elucidation and manipulation of metabolic pathways: courseware developed using Authorware Professional *Biochem. Educ.* **23**, 155-157.
- Jones, M.E., Mann, J.W. and Aucone, M. (1985) Simulated laboratory experiments. *Comp. Life Sci. Educ.* **2**, 76-77.
- Learmonth, R.P., Livett, B.G., Sawyer, W.H. and Jones, S.P. (1988) Multiple applications for computers in biochemical education. *Biochem. Educ.* **16**, 161-164.
- Learmonth, R.P. (1991) Simulation in biochemistry. In “Simulation and Academic Gaming in Tertiary Education” Ed. Godfrey, R., University of Tasmania, 387-394.
- Learmonth, R.P. (1994). Simulated pre-practical exercises (Editorial). *Biochem. Educ.* **22**, 97.
- Pamula, F., Wigmore, G.J. and Wheldrake, J.F. (1995) The use and benefits of computer aided learning in the assessment of a laboratory exercise: enzyme induction in *E. coli*. *Biochem. Educ.* **23**, 158-161.
- Parslow, G. (1993) Report on the Australian workshop on biochemical education 1992. *Biochem. Educ.* **21**, 67-74.
- Scott, K. and Shanley, B.C. (1988) An experience in substitution of CAL for laboratory classes in biochemistry for medical students. In “ASCILITE-88: Computers in Learning in Tertiary Education.” Eds. K. Fielden, F. Hicks and N. Scott. Canberra College of Advanced Education, 204-208.
- Wiseman, E., Denyer, G. and Johnston, J. (1995) Teaching biochemical calculations using interactive multimedia computer tutorials. *Proc. Aust. Soc. Biochem. Molec. Biol.* **27**, POS2-24.