Dry labs in biochemistry departments

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A number of issues in the use of computer-based 'dry' labs were raised and discussed in the plenary session. In this session the focus was moved to discussion of examples and how they have been integrated into laboratory courses. Examples of applications of 'dry' labs were outlined in the areas of pre-practical preparation, data handling and calculations, and combined 'wet' practical and computer simulation. Categorising examples proved to be difficult, given that many examples cover more than one of these areas, or may be applied in different ways either before, during or after practical sessions.. A simulation of protein purification (Booth 1987) was demonstrated, and its use in classes and assessment of outcomes and educational value were discussed. The session concluded with general discussion about appropriateness of various activities and issues involved in implementation.

Assistance with pre-practical preparation

Lack of preparedness of students is a common problem in laboratory courses. Computer-based simulations of experiments have been applied to assist students to prepare for practical work by helping them become familiar with conceptual and numerical aspects of practicals, before coming to the laboratory. In this context I have used a simulation of protein purification (Booth 1987) as outlined below. Another example of this approach may be found in a practical involving estimation of the K_m of b galactosidase (Jones *et al.* 1985). Programs that simulate the operation of equipment such as spectrophotometers, HPLC or NMR instrumentation may be used prior to practical classes for training in equipment use.

Assistance with calculations and data manipulation

Computer programs have been devised to assist in laboratory calculations including general laboratory calculations, buffers, radioactivity and spectrophotometry (Carrington 1993, Pamula 1994, Wiseman *et al.* 1995). Other programs have been used to aid students with calculations integral to manipulation and analysis of data obtained at the bench. Examples include an experiment on induction of b galactosidase in *E. coli* (Pamula 1995) and estimation of the K_m of b galactosidase (Jones *et al.* 1985). These programs emphasise the correct processing and analysis of data, which enhances understanding and interpretation and assists students to draw valid conclusions from their data. In my second year science biochemistry practical classes, I have adopted a combined wet bench practical and computer program package investigating glycolysis and fermentation of grape juice (Pamula and Wheldrake 1994). I found that this exercise provides my students with a useful guide to completing calculations in the context of a real practical situation. Helping students break down calculations into their constituent steps and providing immediate feedback helps address a common problem in biochemistry practical work.

Simulated data acquisition and experiments

Experiments are often simulated because they are too dangerous, prohibitively expensive, too complex or lengthy to carry out in limited practical timetables, or involve procedures that are extremely difficult or impossible for students to perform using available equipment (*e.g.,* rapid reaction kinetics to monitor changes in the concentrations of reaction intermediates). More recently, experiments have been simulated for educational reasons, for example separately addressing the differing objectives of acquisition and analysis of data. The most common approach is to simulate entire experiments or biological processes, for example oxidative phosphorylation (Day *et al.* 1996), investigation of osmosis using red blood cells (Fyfe and Fyfe 1996) and investigation of metabolic pathways in microorganisms (Jenkins and Cartledge 1995). I have participated in development and use of programs that simulate experimental data including effects of environment on enzyme activity, analysis of enzymic reaction intermediates, and binding of oxygen to haemoglobin (Learmonth *et al.* 1988; Sawyer 1972). There are many examples of programs that deal with enzyme kinetics, available either commercially or in the public domain, although many address theoretical rather than practical aspects. Another approach is to combine a 'wet' practical with computer based data simulation, to extend analysis to areas that cannot be covered in a practical session. An example of this approach is investigation of flux through metabolic pathways in a practical on synthesis of urea in isolated hepatocytes (Bender 1986).

Computer-based data acquisition

There has much activity interfacing computers with laboratory equipment, with many research instruments now computer-controlled. There are relatively few examples specifically designed with teaching in mind, however (Learmonth 1995). Examples include experimental data acquisition from oxygen-sensitive electrodes (Learmonth 1987) and spectrophotometers (Titheridge *et al.* 1995).

Simulation of preparative and analytical procedures

The logic, organisation and problem solving aspects of preparative and analytical procedures may be treated separately from the technical aspects by use of computer simulation. Combined with separate training in the actual techniques, these programs may be used as "dry runs" to prepare students for the real work, or to extend instruction to procedures not possible for students to perform. Examples of programs in this category include subcellular fractionation and centrifugation (Smith 1988), protein purification (Booth 1987), protein sequencing (Havlicek and Towns 1979; Place and Schmidt 1988; Vuento and Vihinen-Ranta 1994), gene cloning and sequencing (Smith and Hames 1989) and chromatography (Dramer and Kaars 1987).

A case study — how 'dry' laboratory activities have been integrated into a 'wet' laboratory course

In my third year science biochemistry course, about half of the semester's practical sessions are devoted to purification and analysis of proteins. The practical course begins with a tutorial on protein purification and analysis, based largely on chapter 5 of the text by Voet and Voet (1995). The theory behind the techniques as well as practical aspects are discussed in the tutorial. In the second session, students explore schemes to purify proteins using a computer simulation (Booth 1987). Students had prior exposure to a number of the techniques simulated (*e.g.,* gel filtration, ion exchange chromatography, electrophoresis) in practical sessions in first and second year. In the third session, students revise and practise the estimation of protein concentration and enzyme activity, so that they are better prepared to analyse the fractions produced by various preparative procedures. The final four sessions are devoted to purification and analysis of an enzyme from plant leaves.

I have found this to be a most effective approach to prepare students for a reasonably complicated preparative procedure. I developed this approach in response to problems caused by students being ill prepared for the work at hand. Using the computer simulation, students can make mistakes without costing them days of work. In addition, when they come to the real laboratory work, they have a better idea of what they are trying to do and don't blindly follow recipes given in the practical notes. The whole exercise becomes much more successful and rewarding for the students. It has certainly reduced the number of blunders and conceptual errors that have resulted in the loss of proteins that took weeks to prepare. In future I intend to improve the exercise by condensing sessions devoted to purification and analysis of the enzyme into a two day workshop, to reflect the way it would be done in a professional laboratory.

Conclusions

In conclusion I consider that computer-based exercises can be, and are being successfully used to make our teaching more effective by supplementation and limited replacement of 'wet' laboratory activities. I have found that this works for material developed in-house, and also for material developed elsewhere. Getting over the "not invented here" syndrome can be a major obstacle to the widespread use of computer programs. My view is similar to that about adopting textbooks. Generally we are prepared to accommodate some faults or things we don't like, communicating changes to students. I believe we need to treat computer software in the same way. Most progress will be made in addressing common introductory courses, where local variations can be minimised. It would likely be beneficial to produce materials by consortia of Universities/groups, leading to advantages such as expansion of the feeling of ownership. This does not necessarily imply a high overhead, but can work with collaboration among a network of interested groups or individuals which may extend internationally (Learmonth 1994). A number of biochemistry departments in Australasia are already producing materials, and in 1991, a booklet compiling software use was compiled by the Biochemical Education SIG of the ASBMB (Towns *et al.* 1991). The issues surrounding the use of computers in biochemical education have been given a high profile at annual meetings, and computer-based practicals have been specifically addressed (*e.g.,* Dawson 1992).

Finally, discussions during the workshop identified laboratory courses with up to 50% 'dry' lab sessions. This seems to me to provide an acceptable balance, if the activities are well integrated. There is also great potential to combine 'dry' and 'wet' activities in the same session. Implementation of computer based 'dry' labs has come under much scrutiny, which traditional 'wet' courses seem to have evaded. Reassessment of our practical courses seems to be in order, and 'dry' activities may be applied to address some of the problems we have with current courses.

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 Software.

Carrington, J.M. (1993) An evaluation of computer-aided instruction program on laboratory techniques and calculations. *Biochem. Educ.* **21**, 29-31.

Dawson, A.G. (1992) Practical Exercises or computer simulations? Walking the tightrope. *Proc. Aust. Soc. Biochem. Molec. Biol.* **24**, SYM-16-1.

Day, D., Arundel, M. and Bennett, S. (1996) Oxidative Phosphorylation. A simulated experiment. *UniServe•Science News* **3**, 15.

Drahmer, E.R. and Kaars, J.L. (1987) Microcomputer assisted teaching of chromatography. *Biochem. Educ.* **15**, 140-141.

Fyfe, S. and Fyfe, G. (1996) The osmosis program. *UniServe•Science News* **3**, 16.

Havlicek P.J. and Towns, A.P. (1979) A simulation of amino acid sequencing in proteins. *Chemistry in Australia* **46**, 151-153.

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. (1987) Investigation of oxidative phosphorylation by mitochondria with the aid of an Apple IIe microcomputer. *Biochem. Educ.* **15**, 88-90.

Learmonth, R.P. (1994) Collaborative software development at a distance. *Biochem. Educ.* **22**, 13.

Learmonth, R.P. (1995). Acquisition and analysis of enzyme kinetic data (Editorial). *Biochem. Educ.* **23**, 91.

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.

Pamula, F. (1994) A computer-aided learning exercise in spectrophotometry. *Biochem. Educ.* **22** 192-5.

Pamula, F. and Wheldrake, J.F. (1994) The use and benefits of computer aided learning in the assessment of laboratory exercises at tertiary level. *APITITE 94 Proceedings, Brisbane, Australia* **3**, 933-937.

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.

Place, A.R. and Schmidt, T.G. (1986) *The Protein Sequencing Apprentice.* IRL Press Software.

Sawyer, W. H. (1972) Demonstration of allosteric behavior. The haemoglobin-oxygen system. *J. Chem. Educ.* **49**, 777-780.

Smith, K.R. (1988) *Subcellular Fractionation and Centrifugation*. IRL Press Software.

Smith, K.R. and Hames, B.D. (1989) *Gene cloning and sequencing*. IRL Press Software.

Titheridge, D., Hitchings, E. and Barling, D. (1995) Automated data collection from "manual" Hitachi model U-100 spectrophotometers and analysis by means of Excel spreadsheets. *Biochem. Educ.* **23**, 91-96.

Towns, P., Livett, B. and Parslow G. Eds. (1991) *Computer Assisted Instruction in Biochemistry* . Australian Society for Biochemistry and Molecular Biology.

Vuento, M. and Vihinen-Ranta, M. (1994) A microcomputer simulation of peptide sequencing. *Biochem. Educ.* **22**, 144-5.

Voet, D. and Voet, J.G. (1995) *Biochemistry*, 2nd. Ed. John Wiley & Sons, NY.

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.