CAL-laborate

A collaborative publication on the use of Computer Aided Learning for tertiary level life sciences

June 2000

Learning and Teaching Support Network
United Kingdom

UniServe Science
Australia

BioQUEST Curriculum Consortium
USA
Editorial

This newsletter was conceived as the sibling of CAL-laborate for the Physical Sciences which was first launched three years ago. It is a collaboration between life scientists in the UK, USA, Sweden and Australia and its aim is to reinforce the existing links between science teachers in the international community. Collaboration between university teachers from different nations is never easy to organize or sustain. Part of the reason is because education is very much a political undertaking and we all have different agendas that we are working to – how teachers teach and students learn depends on what culture they come from. Part of it is because the content of what is taught also needs to be customised for local markets – where you live cannot help influencing what you need to know.

The contents of this newsletter are a smorgasbord of activity from the UK, USA and Australia. From the USA, from Beloit College, we have an article on the work of BioQUEST – a curriculum consortium that encourages innovation in biological education by developing and distributing computer based materials that are designed to help students learn strategies of science research.

From the UK we have an article on the ASTER project in psychology at The University of York in which communications and information technologies are being used to support small group teaching. Also from the UK we hear about the eLABorate project (Biochemistry, The University of York) which discusses solving biochemical problems with interactive simulation software. Lastly from the UK, from The University of Manchester, a paper on the use of the Web in data handling in the newly emerged field of bioinformatics, where teaching requires students to have access to large databases.

From Australia and jointly from the Universities of Queensland and Sydney is an article on a taxonomic tool – the LucID project – which is a multimedia expert system that is used to help make correct identifications of biological specimens or correctly diagnose a particular problem. From The University of Sydney we hear about how the Web has been used to create a Virtual Resources Room which gives students easy access to learning resources and enables them to communicate with staff and other students. From Monash University comes a paper on the difficulties of developing ‘virtual touch’. Lastly, also from Monash, with the Olympics soon to be staged in Sydney, is a paper on two biochemical packages designed to look at the metabolic requirements of long distance runners – The Great Metabolic Race, and to help make the decision on where to eat in Sydney after the race – The After Race Banquet.

Peter Miller  Mary Peat  John Jungck
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An Interactive Practical at the Interface of Web-based and Conventional Publishing

Background

When I was a student twenty years ago, I remember being introduced to CAL as part of a chemistry course. I recall being led down to the murky bowels of the department and being ushered into a dull room full of huge VDUs. Having followed the instructions to logon to these prehistoric machines, the class was left alone for 90 minutes in order to complete a computer based ‘project’. Not knowing quite what to expect, this turned out to be little more than a tedious multiple choice exercise, which felt totally divorced from the active learning opportunities provided by tutorials and practicals. To me at least, the entire experience seemed not only odd, but somehow rather pointless.

Today, things are a little different. In the current technological era, far from being confined to special rooms in university basements, computers are fast becoming common pieces of laboratory equipment. It is now almost taken for granted that biologists should have access to up-to-date databases, via advanced interrogation software, and that they should have developed skills to interpret diverse database search outputs. Yet, in spite of living in a highly-advanced, computer-literate age, in which many young people have access to computers in their own homes, persuading biology students not to be afraid of computers can still be surprisingly difficult.

In recent years, the Web has provided new opportunities for innovation in teaching. Web-based approaches allow students to gather information from different corners of the globe, literally at the click of a mouse button. This process attracts mounting interest when different web pages offer added extras, such as animations, or tools with which to commune with data interactively. A great advantage of learning on the Web is that, depending on the design of the teaching material, students may be guided as much, or as little, as a particular course demands. Thus material may be used simply to supplement lecture courses, or may be completely self-contained. In either scenario, armed only with a URL, study may continue away from formal classes. Students may thus explore independently, in a self-paced setting, and compare notes when once again back in the laboratory.

A skills gap

Until recently, traditional biology teaching has not needed to address computational biology. The problem is that biological sciences are now suddenly feeling the impact of the genome projects, and are consequently being flooded with vast quantities of data. This *embarras de richesses* has spawned the field of bioinformatics, which is principally concerned with the acquisition, archiving, analysis and interpretation of these vast quantities of data. This has involved establishing and maintaining databases; designing powerful interrogation and analysis software; and creating tools to help interpret results of analyses in biologically meaningful ways. To achieve this, and to do it well, requires the input of scientists skilled in relevant areas of both biology and computing.

Owing to the fecundity of the genome projects, bioinformatics is a fast growing discipline. Unfortunately, however, the rate of emergence of the field has created a skills gap: while there is an urgent and widespread need for trained bioinformaticians, there are virtually no courses available through which to provide the much-needed training. Postgraduate courses are still relatively rare, and mainstream undergraduate courses almost non-existent. In the meantime, there is a pressing need to make today’s trained biologist more computer literate, a necessary process if bioinformatics is to make a significant impact in solving current post-genome problems.
Embracing the Web

Despite the computer age, teaching computer applications to biologists can still be remarkably difficult, as many students (and their teachers) are ‘silicophobic’ – they may be used to handling systems in vitro or in vivo, but not yet in silico. Nevertheless, the emergence of the Web, coupled with advances in web technology, has provided interesting new opportunities for teaching.

There are several advantages to web-based approaches. For example:

- ‘point and click’ interfaces are easy to use, even for the most computer-wary student;
- data from different sources can more easily be brought together, so teachers need not be expert in all areas, but may direct students to more appropriate expertise on the Internet;
- the use of interactive programs can render data more tangible and visually appealing, and hopefully, therefore, easier to understand and remember;
- the most up-to-date developments in the field can be accessed and exploited; and
- armed with a URL, study may continue away from formal classes, allowing students to work at their own pace, whether at home or on computers elsewhere on the College campus.

However, there are also several disadvantages to web-based teaching:

- Internet traffic can bring work to a stand-still, especially during ‘rush’ hours;
- students can get lost in hyperspace, especially if navigation aids are not made obvious;
- students often don’t bother to read web pages, so even if instructions are available, they will probably never be read;
- ‘point and click’ interfaces are easy to use – so easy, in fact, that clicking from beginning to end of a document designed to occupy a class for 2 hours can (and will) be achieved by some students in a matter of minutes;
- armed with a URL, study may continue away from formal classes – the ideal excuse for some students never to turn up at the laboratory; and
- maintaining web pages is the proverbial uphill struggle – sometimes it seems that no sooner has a page been cast in HTML than half its URLs are already broken!

These are only some of the numerous possible advantages and disadvantages. Thus, while it is easy to put lecture notes and diagrams on the Web, designing effective web-based teaching material is rather less trivial. Obviously, a good tutorial should aim both to capitalise on the powers and to avoid the pitfalls, but this is not as easy as it sounds, because no matter how well you think you’ve thought it through, at least one student will always achieve the unexpected!

In spite of the potential problems, the Web has been embraced with enthusiasm as a teaching medium, and courses and primers in all aspects of science have proliferated. However, some courseware is still little more advanced than the CAL exercises of the late ’70s, involving screen by screen presentation of static information, with embedded questions that allow progress to the next page when answered correctly. Other more advanced courses require registration (and usually fees), but offer greater interaction (e.g. via timetabled virtual meetings in multi-user dungeons) and often certification that the course has been attended or passed.

An interactive bioinformatics web practical

Conventional teaching of bioinformatics has tended to rely on the use of commercial command-line-driven sequence analysis packages. Such programs can be difficult and tedious to use for all but the computer enthusiast, and are opaque and off-putting for bench biologists. In 1995, in an attempt to tackle some of these problems, I developed a short bioinformatics lecture course, which I supplemented with an interactive web-based practical (BioActivity) (see Figure 1), giving students first-hand experience of sequence analysis on the Internet. By contrast with commercial packages, BioActivity provides an interface to analysis resources around the world, so students are not confined to a particular software environment or to a limited commercial perspective.
Inside the practical, as shown in Figure 2, each page carries brief header instructions, coupled with a more detailed commentary and embedded diagrams for those wishing to learn more (I borrowed this idea from the Rupert Bear Annuals I remember reading as a child – it was always exciting to unfold the story quickly by reading the couplets beneath the pictures, but it was ultimately more satisfying to discover the full tale from the free-form prose at the foot of the page. I doubt, however, that any user to date has made the Rupert connection!).

In addition to the instructions and commentaries, further information and suggestions for additional reading are provided in associated ‘info loops’, which are accessed via hyperlinked icons in the bottom right-hand corner of each page (see Figure 3). Much of this background material forms the basis of the accompanying lecture course; although not essential for the practical, students are advised to read it, knowing that most will probably ignore it until examination revision is upon them. Nevertheless, to get the most from the practical, the commentaries urge students to read as much as possible.

Having progressed to the interactive aspects of BioActivity, results of searches are sent to additional left- and right-hand output pages, as shown in Figure 4. This means that the central commentary always remains visible, while allowing results from different database searches to be viewed simultaneously in separate windows (this facilitates both cutting and pasting of information between different pages, and comparison of different search outputs). At the end, references are given to the databases and search tools used, and an extensive glossary of terms is provided. A feedback form allows students to convey comments or problems (anonymously if they wish), so that any obvious difficulties can be quickly remedied.

Figure 2. (a) Page from within BioActivity, showing the list of practical contents, together with header instructions and practical commentary. The consequence of clicking on header instructions is to change the information appearing in the left- and right-hand frames, as seen in (b). The commentary can always be restored using the menu in the header (left-hand side).

Depending on how BioActivity is being used, students may tackle built-in exercise pages before progressing deeper into the practical (Figure 5); this ensures that the different stages have been understood, and encourages students to think about what they’ve done before moving on. Again, depending on context, at the end of the practical, students may be required to write a short report, detailing the main conclusions of the analysis, and placing them in a biological context (for the purposes of this exercise, they are warned not simply to submit pages of output without explanation, but rather to discuss the results in a reasoned and concise manner).

**The practical scenario**

In terms of its content, the practical is built around the following scenario. A molecular biologist has sequenced a number of ‘unknown’ 30-base fragments of DNA. The student is invited to select one of the fragments and, by means of a variety of real-time database searches, to discover the protein family to which it belongs and its biological function. If there is a known 3D structure, this is examined and its structural class uncovered. There are three main stages in the discovery strategy: (i) nucleic acid sequence analysis; (ii) protein sequence analysis; and (iii)
protein structure analysis. The aim of database searching is to discover if a homologue, or homologous family, exists, and to reveal the presence of potential functional sites; interrogation of the structure classification resources then allows rationalisation of functionally important motifs in structural terms. Because the practical is ‘live’ on the Internet, rather than simply offering a collection of canned results, it offers the genuine experience of working with the Web, which inevitably is sometimes good and sometimes bad.
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Figure 5. Example exercise page

Lessons learned

The practical runs adequately on PCs, but may respond differently to different browsers (Netscape Navigator is probably still the best option). BioActivity includes links to some Java software, allowing direct interaction with data downloaded from the Internet. However, in view of the possible problems associated with Java (speed, browser compatibility, available processing power, etc.), these are not core components.

A potential problem with PCs is the tendency of users to fill their screens completely with whatever application they’re running. In the practical, a complication may arise when the main page ‘speaks’ to its left- and right-hand results windows, which will be obscured if the browser occupies the full screen. Of itself, the management of several windows is not a problem, but, surprisingly, it seems to demand a high level of organisation from the students.

BioActivity has been accessible via the Web for several years and is gradually maturing. For example, I now try to provide alternative sites for some database searches, effectively offering ‘rat runs’ to avoid inevitable traffic jams. I have tried to improve navigation aids, so students don’t get lost, but inevitably some still wander! Where possible, I have kept words to a minimum in the central pages, knowing that student attention span is inversely proportional to the length of the text. I have also provided baffles, in the form of short exercises, to delay the rampant ‘point and clickers’.

In every class, there is always a student who manages to finish in half an hour. In theory, forcing the student through the intervening exercises (the answers to which can be discussed, for example, with demonstrators) slows their progress and should make them reflect more carefully upon what they’ve done. Making a written report compulsory also helps to maintain their attention.

In addition to these developments, I have provided soft and hard routes through the practical. In other words, the starting materials (the initial ‘unknown’ DNA fragments) are extremely easy to analyse – their identities are usually discovered in the first exercise. However, once the practical has been completed with easy sequences, a set of ‘mystery’ sequences is available, which are much less likely to yield quick answers – of course, as a stand-alone teaching tool on the Web, anybody may use the practical with his/her own sequence(s). BioActivity is thus suitable for different levels of user, and is adaptable to different teaching contexts.

Assessment and evaluation

The practical requires students to tackle a range of new concepts, including databases and software tools, which they’re meeting for the first time. They must become familiar with a variety of web sites, and not only understand the differences between different types of database, but also the differences between the databases themselves and their software interfaces. Students have to evaluate critically the results from searching the different resources, and present their work as a coherent study, written in the style of a short journal publication.

The practical doubtless has its faults, but it evolves with increasing use and user feedback. To date, responses to questionnaires have been very positive, with 90% ranking the practical as a very useful aid to learning. For the newcomer, it is clear that there is a learning curve to be negotiated, but the overall experience seems to be worthwhile, providing a good foundation for future exploration of bioinformatics resources on the Web. Students moving on to higher degrees have reported that their work has benefited from the practical experiences gained on the course.

Other applications

BioActivity is suitable for use in a variety of teaching contexts, with appropriate modification of the supporting lectures: thus, for example, it is currently an effective tool for undergraduate, MSc and PhD classes, and for staff training. Furthermore, its web-based nature means that the material can be used as a stand-alone resource within a completely virtual environment (e.g. it has provided a core practical component of the Birkbeck College Virtual Course in Protein Structure Analysis5, and will soon be integrated into The University of Manchester’s distance learning course).

A novel twist?

An important recent extension to the practical has been a link to a newly-published textbook6. Or, perhaps more precisely, the book is the natural extension of the practical.
In putting together the initial undergraduate course and preparing the background material for BioActivity, it became clear that there were no textbooks at a suitable level available to recommend as further reading. I therefore used the existing background material as the basis for an introductory book, which leads step by step to a worked example of the practical in the penultimate chapter. In the book there was therefore scope to develop the theories behind some of the practical concepts (which would have been tedious to spell out on the Web), while the interactive practical gives life to the worked example in the book. In addition to allowing me to provide supplementary full colour illustrations (the book is 2-colour only), this arrangement allowed me to keep the theory within the practical relatively concise, and will hopefully encourage students to consult the textbook if further details are needed.

**Conclusion**

Computers are now commonplace in almost all areas of life, from work and commerce to the home. For current generations of students, exposure to computers both at school and at home is more or less taken for granted, and future generations are now playing the latest computer game before they are able to tie their shoelaces! Yet using computers effectively in teaching can still be a challenge. By integrating the solid security of a textbook with the virtual excitement of the Web, in what I hope is a relevant practical approach, I have tried to avoid the sterility of my earliest CAL experience. I hope this will help to make bioinformatics a more accessible subject for biologists, and perhaps spur new generations of students on to MSc or PhD courses – one small step towards bridging the current skills gap.

**References**


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**Simulating Biochemistry: The eLABorate Project**

We are interested in creating opportunities for students to practice applying their knowledge of science in a way which encourages them to solve the kinds of problems faced by experimental scientists. We accept Bodner’s distinction\(^1\) between an ‘exercise’ (which can be solved by a familiar approach) and a ‘problem’ (which involves “doing something when you don’t know what to do”). Our goal is to create situations which are sufficiently clearly defined for solutions to be obtained, but which can be approached in different ways and which may even have different solutions. Much of our work is suitable for biochemists, and some of it has been specifically developed for biochemists; in this paper we will concentrate on the latter. Not all our work is IT-based. For example, we are enthusiastic about the value of original scientific papers in providing a context for discussions of the design and interpretation of scientific investigations\(^2,3,4\). One of the papers we have used successfully deals explicitly with a study of enzyme catalysis\(^5\). Other exercises designed to exercise the skills of thinking are collected in a recent book\(^6,7,8\). However, in this paper, we will confine ourselves to the description and discussion of computer based exercises. Our computer based materials suitable for biochemists are listed in Table 1. They were developed as part of the eLABorate project\(^9\).

We describe our software as *simulations* to indicate that each program simulates some kind of experimental situation. We recognise that this is a very broad concept since virtually any activity set up to provide a learning experience for our students simulates some aspects of reality as closely as possible, but also simplifies reality by cutting out aspects which would otherwise be distracting. The importance of omitting aspects of reality is illustrated by a flight simulator used in training pilots. This simulates with great accuracy the perception of being in the cockpit of a real aeroplane, but the trainee-pilot does not get killed by
‘crashing’ the aircraft. The effectiveness of a simulation depends on the wisdom with which aspects of reality are included and excluded from the simulation.

| enzymeLAB | An exercise in the design and planning of investigations of enzymes which obey Michaelis-Menten kinetics |
| tracerLAB | An investigation of the incorporation of radioactive precursors into protein and nucleic acid during normal growth and after inhibition of protein or nucleic acid synthesis |
| proteinLAB | An exercise allowing the exploration of various procedures for purifying proteins or for designing a procedure for the purification of one from a mixture of 20 proteins |
| immunoLAB | Using antibodies for quantitative assays. This is really two packages, one which deals with radioimmuno assay, and one with elisa; both involve setting up the procedure for determining an unknown. |
| bindingLAB | A visual simulation of protein-ligand binding |
| statsLAB | An empirical investigation of the statistical principles of sampling from a normal distribution and of regression analysis |
| equilibLAB | Titrating a diprotic acid, offering tutor or student choice of the pK values |

Table 1. eLABorate packages dealing with biochemical systems

We have previously suggested four areas in which simulations can be useful. These are:
- as a pre-lab;
- to explore theory;
- to carry out a virtual investigation; and
- to gain experience with expensive equipment.

The last of these is typified by nmrLAB which allows students to control the ‘settings’ of an FT nmr spectrometer and so gain experience of the process of data collection and manipulation as well as data interpretation. In this paper we shall say no more about this type of simulation, but will use two simulations of biochemical systems to illustrate how simulations can fulfil any or all of the first three potential uses. The first of these, enzymeLAB, was originally designed as a virtual investigation; the second, tracerLAB, was commissioned as a pre-lab.

In deciding what experimental situation to simulate, we ask ourselves the following questions:
- Is there an individual teacher who intends to incorporate the final product into their teaching programme and who will be an active member of the development team?
- Is there a clearly defined educational objective?
- Does the computer provide the only (or the best) way of meeting the educational objective? (at the very least the computer must add a dimension to the student activity which cannot be provided in any other way – otherwise we might as well not use a computer); and
- Will the final product be useful to those teaching courses in other universities?

We have always adopted the principle that our simulations are packages not programs: the software does not stand alone, but is intended to be integrated into a coherent learning experience. Our reasoning was that students need guidance in the principles of experimental design and planning, and that this is best learned through interaction with a real person. As we discuss later, we are currently reviewing this principle in the light of changing needs, and also of our experience, some of which we present here.

enzymeLAB

“Congratulations! You have isolated a new bacterial enzyme.” Thus is the student using enzymeLAB greeted.

Almost all students of biochemistry will, during their laboratory course, follow a recipe to collect data from which they calculate \( V_{\text{max}} \) and \( K_m \) for a well characterised enzyme known to obey Michaelis-Menten kinetics. We wrote this simulation so that students could plan for themselves how to collect data for an enzyme for which they could feel some ownership. This meant providing each student with a different enzyme with realistic characteristics. enzymeLAB does this by selecting random combinations of basic values for \( K_m \) and \( V_{\text{max}} \) on which it superimposes randomly selected values for pH sensitivity to these parameters. All the enzymes obey Michaelis-Menten kinetics so that the rate of reaction \( (v) \) is given by the equation \( v = \frac{(V_{\text{max}} \cdot S)}{(K_m + S)} \). The software gives the students information about the specific activity of the enzyme and the sensitivity of the assay procedure since this information would necessarily be available to the isolator of a new enzyme. The computer also limits the amount of enzyme available (as would normally be the case for a newly isolated enzyme). The students are set the task of characterising the enzyme, which they are told involves investigating the optimum pH and the effect of pH on \( V_{\text{max}} \) and \( K_m \). With these aims, the user selects values for the pH and the concentration of enzyme and substrate at which the rate of the reaction is to be measured; the resulting value of \( v \) which is displayed has a realistic experimental error with a standard deviation of 5% of the correctly calculated value.

Our view is that an effective investigation involves the use of the following rules of thumb:
- The \( K_m \) for most enzymes falls within the range 1uM to 1mM. It follows that:
  - (i) at a substrate concentration of 20 mM, most enzymes are saturated \( (v = V_{\text{max}}) \); and
  - (ii) measuring \( v \) at \( S = 20\text{mM} \) and \( S = 0.02\text{mM} \) will provide information from which a rough value for \( K_m \) can be determined in a further one or two measurements.
- Any assay procedure can measure rates only over a limited range; to maximise the range of values of \( S \) at which rates can be measured under identical conditions, the concentration of enzyme chosen should

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give a value of $V_{\text{max}}$ close to the upper limit of the range.

- To determine $K_m$, it is desirable to make measurements of $v$ at substrate concentrations ranging on either side of $K_m$ (say from 0.2 to 4 $K_m$).

It soon became apparent that second year students lack the experience to apply their basic knowledge of enzymes in this way. We therefore prepared a set of self-test questions designed to bring out the key principles (examples are given in Table 2). Most students were insufficiently motivated to complete these. We therefore now arrange a pre-simulation class for which students prepare answers to the questions, and at which the tutor calls on students at random to provide answers which are then discussed by the class. With this pre-exercise guidance, students are able to complete the computer based simulated investigation without a tutor being present, thus allowing them the flexibility to choose when to spend time at the computer. This need for tutorial input illustrates our point that these simulations are ‘packages not programs’.

1. If you want to study the sensitivity of your enzyme to pH would you aim to work at a substrate concentration which always saturates the enzyme or never saturates the enzyme?
2. You are told that the specific activity of the enzyme was measured at a substrate concentration of 20mM; why was this value chosen?
3. Devise a strategy for finding an approximate value for the concentration of S needed to achieve a rate of approximately half the maximum rate at pH 7 using not more than 4 measurements of rate.
4. Plan how you would like to space your values of S to achieve a desirable range of values of rate.

Table 2. Pre-exercise tasks in preparation for enzymeLAB

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Although we originally wrote this software to allow students to carry out what we have called a ‘virtual investigation’

4, it is in practice a much more versatile tool. We have, for example, used it for three years with a group of first year biochemistry students. For these students, the task they are set is simplified and is completed in a single day.

An important feature of the computer simulation is the speed at which it can generate data. Data which would take two or three weeks to collect at the bench can be generated by the computer in two to three hours. Furthermore, the data are of a quality which would be obtained by an experienced professional. This quantity and quality of data is sufficient to justify the requirement that each student writes a report in the style of a scientific paper. We have described our experience of this.

With hindsight, we can suggest improvements to the design of the software which would increase the flexibility of the package. For example, it would be useful to allow the tutor to vary the error function (or to remove it altogether). A particular regret is that we have not built in an option for the tutor to define the characteristics of the enzyme or to select a specific set of the parameters stored in the program. This facility would add a new dimension to the use of enzymeLAB in conjunction with laboratory work using a real enzyme.

Opinion varies whether the optimum combination of a simulation and laboratory work involves using the simulation first (as a preparation to understand the thinking behind the recipe in the laboratory manual) or after the benchwork (to allow the students to explore more fully the data available from enzyme kinetics when they have a good appreciation of the laboratory context). Booth has used his simulation of protein purification (proteinLAB) both to prepare students to purify a protein in the laboratory, and to broaden the experience of students who have already carried out a purification protocol. His conclusion was that students generally felt that they would have gained more by doing the two exercises in the reverse order to the one they actually used!

**tracerLAB**

This simulation was written specifically as a pre-lab to support a laboratory class in which first year biochemistry students follow the uptake of $^{14}$C-adenine into protein and nucleic acid when bacteria grow normally and after the inhibition of protein synthesis or after uracil starvation. The software simulates two types of labelling experiment. The ‘cumulative label’ calculates the amount of label which accumulates in protein and nucleic acid when the labelled precursors are present throughout the incubation. In the ‘pulse label’ the culture is incubated without labelled precursors, samples are transferred at selected times into an aliquot of labelled precursors, and the program calculates the amount of label incorporated in one minute. A brief description of the program has been published.

In the laboratory class, students are required to select one of three strains of bacteria, TAUbar, BW113 and SH7. TAUbar cannot grow unless uracil is present in the incubation medium. The other two strains differ only in that SH7 has ‘stringent’ control over RNA synthesis (synthesis of tRNA and rRNA is inhibited when protein synthesis is inhibited), whereas BW113 has ‘relaxed’ control (it continues to synthesise tRNA and rRNA when protein synthesis is inhibited). The students also chose one of three ways of inhibiting growth (addition of valine to inhibit iso-leucine synthesis, addition of chloramphenicol, or limitation of uracil in the incubation medium). They also make their own decisions about the amount of radioactivity and carrier to add to the medium, and the times at which to add inhibitor and take samples for analysis. Identical options are provided by the simulation, which is built on realistic models of all three strains of bacteria.

The simulation allows them to test out their proposed protocol, to discuss the results with a tutor if necessary, and to revise their protocol as many times as necessary for them to obtain interpretable data. Common mistakes made in early protocols include adding insufficient carrier so that bacteria use up all the label before the end of the incubation (or so much that very little label is taken up), adding insufficient label (particularly early in the incubation...
period) so that too few counts are taken up, and failing to take sufficient samples to establish the pattern either of the uninhibited exponential growth or of the post-inhibition incorporation.

In order to minimise poor decisions of this sort, the students must enter the concentration of radioactive counts and of carrier they propose to use. Their next step is to enter the volumes of solutions of radioactive tracers and of carriers. The calculations involved are not trivial, and require the application of basic knowledge, which students should have, but have rarely used in this way. For example, they have to handle concepts like specific activity and counting efficiency in order to convert the specific activity of their stock solution of tracer into a count rate in their samples, and they need to use the expected growth rate of the bacteria together with the composition of protein and nucleic acid to calculate how much lysine and adenine will be incorporated into protein and nucleic acid during their chosen incubation period.

`tracerLAB` includes two features not incorporated into `enzymeLAB`. One is an animation which students can access at any time and which shows a diagrammatic representation of the procedure from the setting up of the incubation flasks, through the preparation of samples, to the counting of the radioactivity with a scintillation counter. This helps to create a bridge in the student’s mind between the artificial nature of the simulation and the reality of the laboratory. The second feature is the hidden code which allows the tutor to decide whether to use the software as a pre-lab (when students choose the strain of bacterium they wish to study) or as a virtual investigation (when students are allocated one of the three strains by the software, and are set the task of characterising it).

**Conclusions**

**Writing simulations**

Considerable investment of time is required to create an effective simulation. It is therefore important to maximise the eventual use of the software, and this means making it sufficiently flexible for tutors to adapt it to their own needs. Our approach to this is to write a simulation only on the specific request of a tutor (our expert advisor) who intends to incorporate it into the curriculum for a specific and defined purpose. This means that we can be confident that it will be used in at least one institution. However, we also satisfy ourselves that the subject of the simulation is of sufficiently general interest that it will be found on the syllabus of most comparable courses. The expert advisor must provide us with a realistic model on which to base the simulation, though experience shows that we can have a crucial input (as non-experts) at this stage, either because our own unfamiliarity with the system can lead us to ask ‘naive’ questions which have been overlooked, or because our familiarity with the capability of the computer can help to determine whether a particular approach is too complex or could be improved. Another important role we play in the development process is to use our experience from other simulations to suggest ways in which the program can be made more flexible; we have described above how we increased the flexibility of `tracerLAB` beyond its originally specified role as a pre-lab exercise.

We aim to use what we have called a ‘functional’ rather than a ‘flashy’ interface; in our view too much software looks as though it has been written by computer enthusiasts wanting to make the maximum use of multimedia technology, without considering carefully enough the educational advantages (or more often disadvantages) of doing so. We acknowledge the usefulness of high quality videos for some specific purposes, but we believe that well designed diagrammatic representations are in many cases clearer and more useful.

**Student feedback and reflection**

Much of the feedback we receive from students is positive. However, we have experienced two different kinds of negative feedback. One comes from analysis of the results of tests or questionnaires completed by students before and after completing a simulation. As an example, we have reported the data obtained from a group of first year biochemistry students who used `enzymeLAB`. The two-part questionnaire tested student knowledge of basic aspects of enzyme kinetics, and recorded their self-assessed confidence in their ability to apply this knowledge. We found little evidence that any increase in knowledge or confidence persisted six weeks after completing the exercise. However, we regard this as understandable; we should not expect a single three-hour exercise to have a huge effect on student learning, especially since most students’ primary aim is (understandably) to obtain the maximum mark for their degree for minimum work. This encourages them to look forwards (to a new piece of assessed work) rather than backwards to a completed piece of work in order to consolidate their understanding of it. Our view is that this demonstrates the importance of providing students with a formal opportunity to reflect on the lessons learnt through a particular exercise. This is rarely if ever achieved simply by handing back a marked script, but requires a formally timetabled class in which students discuss lessons and conclusions.

The second type of negative feedback (which is rare for `enzymeLAB` and `tracerLAB`) is the view of some students that the simulations do not provide an agreeable or effective learning experience. These subjective views are, of course, highly coloured by student expectations. We believe it is significant that when a majority of students have negative views about their experience (as is usually the case with `statsLAB`), the minority who find it a valuable experience almost always comment that they were made to think. Our conclusion is that most students have come to regard biochemistry (or chemistry) as a subject in which correct answers to all relevant questions are known, and that the student’s job is to find the correct answer. They cannot treat the simulations as an exercise (in Bodner’s sense) since they have to apply their knowledge in a flexible and creative way. Many find this difficult enough to be demotivating. The solution to this must be careful preparation to ensure that they understand both how to approach the exercise and why it is an important aspect of their learning experience.
Thus our conclusion is that the effectiveness of a simulation depends not only on how well it is written in the first place, but on the individual input from the tutor both in preparing the students appropriately and in debriefing them appropriately.

**Distance learning**

Much computer based learning material is designed to provide a complete and self-contained learning experience for the student. In contrast to this approach, we have designed our simulations on the assumption that students will have direct contact with a tutor. We recognise that this is a limitation in so far as the assumption makes the simulations less than ideal for incorporating into programmes of distance (or fully independent) learning. We have therefore given some thought to ways in which the need for direct input from the tutor can be removed, or at least minimised. The difficulty of doing this stems from the fact that most of our simulations require the application of knowledge, rather than its acquisition.

Consider, for example, the pre-exercise tasks used as part of the preparation for using enzymeLAB shown in Table 2. Direct answers to these questions cannot be found in textbooks; indeed they are not the kind of question to which a single correct answer can be given, although some answers could be classed as ‘better’ than others. They are well suited to our current procedure of setting them for students, and then discussing their answers in class. It would be possible to devise material (either paper-based or computer based) which would provide support for the motivated distance-learner. But the application of knowledge is a skill which we believe involves not just ‘learning by doing’ but also at best it involves direct interaction with experienced practitioners. If this were not the case, there would be little point in meetings and conferences at which practicing scientists exchange ideas.

We remain of the opinion that a good tutor will always be better than either a book or a computer program. As Boothroyd put it\(^4\), in most of our teaching we invert the intellectual hierarchy of knowledge, understanding, and skill in application by spending our valuable contact time covering content (which can be learned in a variety of other ways), and have too little time left to deal adequately with the higher order skills involved in the application of knowledge. Our aim must be, not to replace the tutor, but to create conditions in which tutorial input can be saved for the kind of learning which is the most intellectually demanding.

**References**

9. The eLABorate project was funded by the University Funding Councils of England, Scotland, Wales and Northern Ireland under the Teaching and Learning Technology Project.

**“Crossing the Chasm” of Curricular Reform: BioQUEST Curriculum Consortium Invites CAL-laboration**

The BioQUEST Curriculum Consortium supports and encourages innovation in bioscience education through the development, distribution, and field testing of computer based curricular materials that have been designed to help students learn long-term strategies of research. BioQUEST is an acronym for Quality Undergraduate Educational Simulations and Tools in Biology, reflecting its initial focus on the development of curricular resources for biology educators through *The BioQUEST Library*. The Curriculum Consortium emphasizes investigatory and collaborative learning strategies for problem solving in the biological sciences. To these ends, workshops for faculty development, multiple presentations, and publications by staff and collaborators are provided each year. A communication network for committed educators is maintained by the organization.

A major challenge to curricular reform efforts is to reach beyond early adopters and adapters in undergraduate biology education to a larger sector of biology educators. The BioQUEST Curriculum Consortium would like to collaborate internationally to address four foci: complex problem solving; collaborative learning; use of computer simulations, tools, and digital libraries in original
research or research-like experiences; and networking innovators.

The BioQUEST Curriculum Consortium is in its fourteenth year. Our intellectual predecessor, CUEBS (Commission on Undergraduate Education in the Biological Sciences), one of the longest undergraduate reform efforts in the United States in this century, lasted from 1964-1973 (nine years). Persistence is critical to sustain reform in order to provide support for educators who take the risks of experimenting with their pedagogy, curricula and curricular materials.

During 1986-1993, most of the BioQUEST focus was on the development of innovative software designed to help students learn long-term strategies of research. This phase culminated in the publication of the first edition of *The BioQUEST Library* (1993). In a model of change popular in Silicon Valley (see Figure 1), our first seven years primarily involved working with ‘innovators’, both from pedagogical and technological perspectives.

In our second seven year phase, 1993-2000, we have been successful in engaging ‘early adopters’, who have adopted and adapted materials published in *The BioQUEST Library* for their classroom, laboratory, and field curricula. This outreach was accomplished through publications, workshops, presentations, and continued development of software. *The BioQUEST Library*, now published by Academic Press, grew from 17 modules in Volume I to over 65 modules in Volume V. Over 140 colleges and universities purchased campus site licenses and many more have individual licenses. Our free newsletter, BioQUEST Notes, is distributed to between five and six thousand subscribers, mostly college and university biology educators. We share extensive information through our web site, http://bioquest.org/. In addition, a network of individual and group field testers participate in design and refinement of curricular materials and we host 24 to 40 professors per year for a nine-day summer curriculum development workshop at Beloit College. We encourage interested biology educators to join us!

As shown in Figure 1, most innovators find crossing the chasm from early adopter to early majority difficult. *The BioQUEST Library* is our catalyst of curriculum reform. It allows us to demonstrate our philosophies in action. This diverse collection of modules (Figure 2) that have been systematically tested in classrooms and laboratories provides both resources and support for adopters/adapters who want to incorporate problem solving into their curricula. For faculty, the ability to instantiate our philosophy in software environments that support systematic problem solving and realistic research-like strategizing has been critical to opening previously closed doors.

**The BioQUEST Library**

We will discuss our experience with five different components of *The BioQUEST Library*: strategic simulations; tools; digital libraries; case studies; and decision-making.

Currently, BioQUEST has support for three initiatives: (1) to develop curricular materials and research bases in bioinformatics, ecology, evolution, and microbiology education and develop digital libraries for undergraduate research and education; (2) to develop on-line resources for and with two-year community college biology educators; and (3) to expand the BioQUEST community of users of technology in democratizing opportunities for greater participation in open-ended problem solving and research in undergraduate biology education. As we begin our next seven-year phase, our focus is to extend problem posing, problem solving, and peer persuasion resources for undergraduate biology curricula.

As shown in Figure 1, most innovators find crossing the chasm from early adopter to early majority difficult. *The BioQUEST Library* is our catalyst of curriculum reform. It allows us to demonstrate our philosophies in action. This diverse collection of modules (Figure 2) that have been systematically tested in classrooms and laboratories provides both resources and support for adopters/adapters who want to incorporate problem solving into their curricula. For faculty, the ability to instantiate our philosophy in software environments that support systematic problem solving and realistic research-like strategizing has been critical to opening previously closed doors.

**Strategic simulations**

Numerous simulations have been constructed which are designed to help students engage in the exploration of open-ended problems and offer complex data sets, opportunities to manipulate multiple variables, multidisciplinary tools for exploration, and numerous modes of data analysis and visualization. These ‘microworlds’ allow students to investigate contemporary research problems, to explore ‘what if’ questions, to pose new problems, and to examine fundamental concepts as well as classical experiments. In order to explore the potential of a rich simulation in considerable depth, students find these learning environments are content rich.
and process rich. Students are challenged to understand which tools are appropriate in which contexts and why one tool is more powerful than another. Surprises can arise if students have committed themselves to models or predictions of behavior that can be examined for contradictions, axioms, inadequacies, or the falseness of their own mental model for causation.

Strategic simulations encourage student ownership of the research/problem solving agendas, combine mathematics into scientific exploration, and lead to quantitative skill development and interpretation of multiple visualizations of data. Simulations offer flexibility of use in classroom contexts (e.g. case studies, investigative laboratories, homework, and distance education) as well as local contexts (e.g. experience and talents of students and teachers) which enhance conceptual integration and conceptual change. Simulations provide students with the opportunity to explore problems/experiments that would otherwise be considered:
1. too risky (safety issues);
2. unethical (destroy biodiversity, medically too intrusive, unnecessary use of animals);
3. too expensive (but note NOT in replacement of wet laboratories);
4. take too long (requiring multiple life cycles, multiple trials);
5. too difficult (requires special laboratory skills);
6. inaccessible (no link to research databases, enhanced data-mining and, in some cases, the opportunity for students to do original, open-ended research as opposed to research-like inquiries); and
7. out-dated (replicate aspects of historically important models/classical experiments).

Screen shots from simulations in The BioQUEST Library are provided in Figures 3 and 4.

Strategic simulations make use of the ten characteristics shown in Table 1 (Jungck and Calley, 1986).

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Novelty of problems each time that a program is run</td>
</tr>
<tr>
<td>2.</td>
<td>Realistic outcomes for each experiment performed</td>
</tr>
<tr>
<td>3.</td>
<td>Infinite opportunities to perform experiments</td>
</tr>
<tr>
<td>4.</td>
<td>Computational power</td>
</tr>
<tr>
<td>5.</td>
<td>Speed in obtaining results</td>
</tr>
<tr>
<td>6.</td>
<td>Large, complex data sets</td>
</tr>
<tr>
<td>7.</td>
<td>Facilitates successive hypothesizing and logical and numerical testing</td>
</tr>
<tr>
<td>8.</td>
<td>Sequentially developed problem difficulty involving an increased quantity of natural phenomena</td>
</tr>
<tr>
<td>9.</td>
<td>Solutions as hypotheses</td>
</tr>
<tr>
<td>10.</td>
<td>Collaboration and peer review</td>
</tr>
</tbody>
</table>

Table 1. Features of strategic simulations

![Figure 3. SequenceIt! (Place and Schmidt)](image)
Tools
Tools have fundamentally changed the nature of the science that can be done and by whom. For example, with the advent of computers, biological systematics has been dramatically transformed. Two such powerful tools in The BioQUEST Library are MacClade 2.1 (Maddison and Maddison), and Phylogenetic Investigator (Brewer and Hafner). Mathematical tools for measuring Fractal Dimension (Boston University) and ascertaining if deterministic chaos is present in biological populations (Wimsatt and Schank) are also included. A widely used tool, NIH Image, is a freeware package that we make available. It allows users to transform any picture into quantitative data that can be used to test hypotheses quantitatively.

Digital Libraries
Another variety of software that promises to be of broad interest to the biology education community involves rich, complex data sets focused on a particular phenomenon. The BioQUEST Library includes our digital library on Darwin’s finches and the Galapagos Islands (Figure 5) and features a student interface with the Biology WorkBench, a bioinformatics environment for downloading and analyzing sequence data completely through the use of web-based tools, developed in collaboration with the University of Illinois Urbana Champaign and the University of California San Diego. (http://bioquest.org/bioinformatics/)

Data can be easily exported to spreadsheets and statistical analysis software so students can quantitatively test hypotheses.

Case studies
Getting started with simulations, tools and digital libraries may be facilitated with the use of case studies. Ethel D. Stanley, Director, BioQUEST Curriculum Consortium, and Margaret A. Waterman, Assistant Professor of Biology, Southeast Missouri State University, have developed case studies and are collaborating with two-year faculty on a web-based project: LifeLines OnLine: Curriculum and Teaching Strategies for Adult Learners. (See an example at http://bioquest.org/llnsta/)
BioQUEST cases for biology are open-ended and draw from a broad range of applications in biology. Students move beyond an initial searching for ‘facts’ related to the questions they are exploring to investigate biological phenomena. What sets this approach apart from other problem-based learning is an emphasis on a research-like environment for learning biology. This investigative case-based approach encourages problem posing, investigation and persuasion. Although the problem space is defined by the case, students are not only asked to learn relevant material, but also to pose a question, develop accountable approaches to investigate it and present methodology and conclusions to the class that support a reasonable answer.

![Figure 6](https://example.com/figure6.png)

Figure 6. As an alternative teaching/learning strategy, case studies facilitate student exploration of their own questions rather than what might be asked on an examination.

LifeLines OnLine materials integrate information technology with investigative case-based learning (ICBL) pedagogies. Students work to develop questions and reasonable investigative approaches, gather data and information, test their hypotheses, and work to persuade others of their findings. Using a variety of resources (including traditional laboratory and field techniques, software simulations and models, data sets, web-based tools and information retrieval methods), students develop problem solving strategies for lifelong learning in the context of investigating biological problems that they find meaningful.

Values and decision making

The purpose of reform in biology education is to have biology students understand and apply the process of science, not just its products. Although current biology courses introduce life science concepts to undergraduates, the “curriculum and pedagogies often fail to prepare students to use what they have ‘learned’ to solve real problems” (Stover 1998). Students should connect the biology they learn with the biological issues they face each day. While inquiry, or “asking a good question, as well as accessing, locating, evaluating and using information” is critical in scholarship, these skills are invaluable to an even greater degree in making daily decisions (Ercegovac and Yamasaki 1998). In order to develop lifelong strategies for problem solving, the biology curriculum must provide opportunities for students to direct their own learning as they explore the science underlying realistically complex situations. Students work collaboratively to identify issues, to frame questions of interest to them, and then to identify additional information in answer to their questions.

![Figure 7](https://example.com/figure7.png)

Figure 7. Dan Udovic and colleagues at the University of Oregon developed this model to emphasize the integrative aspects of decision making.

Conclusion

The BioQUEST Curriculum Consortium is eager to learn about successful pedagogical and technological innovations in biology education from science educators in Australia, Sweden, and the U.K. We hope that by CAL-laborating with a larger community, we collectively can “cross the chasm” of biology education reform.

References

Myers, C. http://www.spin.org/Myers/ld015.html
LucID: A Multimedia Educational Tool for Identification and Diagnostics

Abstract

LucID is a multimedia expert system designed specifically to help users make a correct identification of a biological specimen or to correctly diagnose a particular problem. The program comes in two parts, a builder used in the creation of keys, and a player that enables the user to identify specimens or to diagnose a problem using the key. A major feature of LucID is its ease of use. This and other features of LucID are described and a number of examples are provided of how LucID is being used for identification and diagnosis, and to access information relevant to the item that is keyed-out. The role LucID is playing in recent decision support and training systems is outlined. Future possibilities for LucID are explored, including the role it can play in distance education, in training users to make accurate observations, and in teaching the logical processes involved in creating keys.

Introduction

Biologists, conservation specialists, quarantine professionals, and those involved in biodiversity and environmental impact assessment rely on the correct identification of organisms to analyse problems. In many professions, identification and diagnostic skills are 'out-sourced'. To identify an unknown insect, for example, the specimen is often sent to a specialist. However, the increasing shortage and/or cost of providing this specialist expertise means that this course of action is often not feasible, posing a major impediment to improved resource management. At a time when biodiversity professionals are in increasing demand and accelerated identification processes are needed, taxonomy is being squeezed out of the university curriculum through competition for diminishing resources with the new technologies of biology. Thus, for practical resource management as well as for the classroom, there is an increasing need for easy to use identification and diagnostic tools.

Interactive, multimedia keys are one way of resolving this taxonomic crisis. They provide a mechanism for transferring taxonomic expertise into a form that is easily accessed and employed by non-taxonomists. LucID is a multimedia identification and training tool, developed at The University of Queensland. It has become popular because of its ease of use – both in creating guides to identification and as a source of information. Originally designed for taxonomic identification, LucID is also being used for much broader diagnostic purposes. Collaboration of experts to produce LucID keys is proving to be an exciting and cost effective way of consolidating dispersed knowledge bases.

This paper consists of four sections:
• a description of the LucID system, consisting of the key builder and the key player;
• examples of LucID keys to illustrate the various ways in which LucID has been used to build identification and diagnostic keys across a range of disciplines;
• the role of LucID in the university; and
• the potential for LucID in the future, as a multilingual, CD-ROM/Internet product.

The LucID system

LucID is a research, educational and decision support tool that enables the user to identify specimens, such as biological taxa, or to diagnose problems, such as sick
The LucID system consists of a Builder and a Player. The Builder allows teachers, lecturers, taxonomists or decision support developers to build and modify identification or diagnostic keys to meet the particular requirements of specific users. The Player allows users to browse LucID keys, which can incorporate text, images, video, and sound to help the user select those taxonomic and diagnostic characteristics which best describe the particular case being investigated. As the user selects character states, those taxa or causes of the problem to which these character states do not apply are rejected, reducing the list of possible taxa or causes. Once the specimen has been identified to a particular taxon or a diagnosis made, LucID then provides multimedia fact sheets, sub-keys, or links to web sites for further information or recommendations.

For the last 200 years, dichotomous keys provided the main way in which users could access expert knowledge in order to identify specimens. These paper-based keys consist of a series of questions about characters, the user starting with the first multiple choice question. The character state chosen from this multiple choice directs the user to the next question to be addressed. In this way, the user moves up a branched tree to finally reach a specific taxon at the tip of a branch.

As well as being time consuming and often tedious, dichotomous keys do not offer the user a choice in the sequence of characters investigated. This can be a major problem if the user is unable to answer a specific question. By contrast, open access keys, such as LucID, allow the user to decide in which order to work through the characters in the key, depending on the specimen being investigated and the user’s ability to distinguish between different character states. The addition of an ‘expert route’ facility to LucID, which guides the user along a sequence of characters an expert would recommend, provides the option of using LucID both as a dichotomous key and as an open access key.

The following screen dumps illustrate how the LucID Player operates. The first screen shot is taken from a key to urban pests. It shows the four LucID windows that provide the main interface between the user and the key. In this particular key, 35 characters with multiple states are available to choose from to identify 27 urban pest taxa.

LucID provides a full multimedia capability that allows the user to look at images or videos to help in determining which character state is most appropriate for the particular specimen to be identified. In the example below, the user has clicked on the information box to the left of the character state ‘bug-like’ and an image of that character state has appeared.

More detailed character states can be viewed – first as ‘thumb-nails’ which can then be zoomed up to a full image – in this case, “Wing position at rest: Wings held at right angle to body”.

In the final screen shot, the selection of four character states have led to the identification of a particular taxon – the subterranean termite. By clicking on the information box next to the taxon name, text, images, video and other multimedia can be accessed, providing further information about that termite.
LucID keys can be built in various languages and use terminology familiar to the user, allowing the package to be used internationally, across a wide range of abilities. Potential users range from biologists, geologists, agriculturalists and veterinary and medical scientists to university and high school students and the general public. For more information about LucID and for an up-to-date list of LucID keys, visit http://www.lucidcentral.com/.

Examples of LucID keys

The following three keys illustrate how LucID is being used in different disciplines for different purposes:

A key to Australian Aquatic Invertebrates (Version 2)

This key, developed by Ben Gunn, John Trueman, Sophia Dimitriadis and Peter Cranston, provides a series of keys to help those with little background in invertebrate taxonomy to identify fresh water macro-invertebrates. This key is particularly relevant for environmental science students who use invertebrate diversity as a measure of water quality. On opening the CD-ROM, the first key the user encounters is the ‘top’ key, which provides assistance in determining to which major group the specimen belongs—such as sponges, jellyfish, roundworms, leeches, crustaceans and so on. The user can obtain information at this level of identification or, in half the cases, can proceed to a more detailed identification by pulling up a sub-key to that specific group: over 30 sub-keys are available. Throughout the identification process the user is helped by over 1500 images to illustrate possible character states and glossaries that explain technical aspects.

Diag Nostic key for mouth ulcers

Laurie Walsh and Alex Forrest of the School of Dentistry at The University of Queensland have developed this key for use by undergraduate students. Their aim is to demonstrate diagnostic pattern recognition, which is the major approach used by experienced clinicians. The key addresses the problem of diagnosing 29 different conditions which can appear as ulcers in the mouth. These range from common conditions, which affect a large proportion of the population, to rare lesions. Eight characters are used in the key in a sequence that a clinician would apply for gaining further detail about the patient, their condition, and the lesion itself. This emphasises the need for a systematic approach in the diagnostic process. The eight characters are:

- history (e.g. first presentation or recurrent presentation);
- systemic signs/symptoms (e.g. fever, malaise, diarrhoea, night sweats);
- local signs/symptoms (e.g. swelling, lymphadenopathy);
- pain—in terms of severity;
- precipitating factors (e.g. medication usage, trauma, stress, corrosive chemical exposure, dental treatment, anti-cancer chemotherapy, radiation, immune suppression, malnutrition);
- number of ulcers;
- site of ulcer(s) (14 different regions of the oral cavity); and
- ulcer border (e.g. undermined, indurated, pseudomembrane).

An important feature of LucID is that it allows the key builder to use a ‘commonly mistaken’ score, when developing the key, to allow for difficulties the user may have in correctly determining character states. This may mean that those using the LucID key may not be able to key out a single final diagnosis but be left with a few possible conditions, which will need to be discriminated by histology, serology or other means.

The third example illustrates that, although LucID keys can be developed as information products in their own right, they are also being used as a component in more general training and decision support products.

Urban pest control

A commercial CD-ROM product has recently been developed at The University of Queensland to provide training and decision support for urban pest control operators in Australia. The CD-ROM includes a number of modules that address the main issues determining the operator’s competency, such as pest monitoring, pest identification and choosing the most appropriate pest control measure. As well as video clips, fact sheets and links to the web sites of pesticide manufacturers and suppliers, the CD-ROM includes four LucID keys to help the user diagnose timber damage problems and identify stored product and other urban pests. Keys and relevant modules from the CD-ROM are being adapted to enhance an urban entomology undergraduate subject, which is offered to remote students via the Web, CD-ROM and printed notes.

The role of LucID in the university

A number of LucID keys already developed have wide suitability for use in undergraduate and postgraduate teaching. The list of keys below gives an indication of the range of topics covered:

- Eucalyptus of South Eastern Australia;
- Families of Flowering Plants of Australia;
- Wattles of the Kalanie Region;
- Identification guides to mites and thrips;
- Insects found in cotton;
- Staghorn Corals of the World;
- Mosquitoes of Torres Strait; and
- 80 Common Minerals.

At present, three universities (The University of Queensland, The University of Sydney and The University of Adelaide) are participating in a LucID-based CUTSD (Committee for University Teaching and Staff Development) funded project called ‘BioED: Biodiversity and education in an interactive, multimedia environment’. BioED will be a structured CD-ROM package of LucID keys and taxonomic information on major groups of organisms (bacteria, Protozoa, arthropods, plants and frogs). The project has three goals:
1. to develop new identification tools (LucID keys) for CD-ROM and the Internet to enable us to teach organismal biology subjects more effectively;
2. to provide a tool for restructuring and rejuvenating laboratory sessions concerned with the identification and classification of organisms; and
3. to stimulate a chain-reaction in other tertiary institutions within Australia with new and additional taxonomic keys that are not only easier to use but are educationally superior to traditional keys.

We believe LucID has the potential to reform teaching methodology in this important area of the biological sciences through students browsing developed keys and by them developing their own keys. For instance, the LucID Builder has been utilised effectively in advanced student projects to teach the principles of key development. Students are not only required to observe, understand and often draw the important characters of the group involved, but also learn additional skills such as electronic image manipulation and how to incorporate video and audio components into their keys.

**Future potential for LucID**

LucID is the product of five years research and development, involving participants from a number of research, university and industry organisations in Australia and elsewhere. For instance, collaboration with colleagues in the Asia-Pacific region has led to the development of versions of the LucID Player in languages other than English, including Mandarin, Bahasa Indonesian and Vietnamese. Development of players for other languages will be an important priority in the future.

The LucID project is ongoing and, in response to users’ requests, we have recently developed and are currently beta-testing a web-based version of LucID, which allows users to access keys from any web site. This new version, which can be used for CD-ROM as well as web-based keys, has a number of added features, such as supporting HTML and offering a wide range of image formats. Clearly, LucID has broad potential for use in distance education by providing exciting, interactive and diverse ways to present large amounts of taxonomic and diagnostic information.

**Acknowledgements**

We wish to express our thanks to colleagues at The University of Queensland involved in an Action Learning project, as well as those involved in the CUTSD BioED project, for discussions concerning the educational uses of LucID across a range of disciplines.

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**Virtual Communication for Lab-based Science Teaching: A Case Study**

*This paper is a slightly modified version of a paper presented at the Computer Based Learning in Science, CBLIS’99 conference. It is reprinted here with permission from CBLIS’99.*

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**Introduction**

“Effective university teaching is about making learning possible. There can be no excellence without changes in understanding. Changing understanding ... can only be done by shaping experiences for students that encourage them to learn”.

In recent years students around the world have been demanding greater input into their tertiary studies, including more involvement in setting learning contracts, a greater say in deciding what assessment tasks are suitable for them and in particular they are demanding greater flexibility in the way they receive their instruction. As academics we, in Australia, are being pushed willingly or unwillingly along new routes to investigate and experiment with course delivery strategies that fulfil our students’ expectations. For many of us the new route has been to look at on-line delivery of learning materials, which is neither new nor the panacea for all problems, but it does offer teachers and students a more flexible mode that may suit certain teaching activities but more importantly may suit the learning style and commitments of some students. A mix of face-to-face activities and on-line activities together form the basis of many university courses today. Candy, Crebert and O’Leary suggest that courses which enhance lifelong learning must offer some flexibility in structure and provide for development of self-directed learning. They state that teaching in such courses must make use of open learning delivery mechanisms, where appropriate, and should make use of peer-
assisted and self-directed learning. Open Learning is defined by Paine as “a process which focuses on access to educational opportunities and a philosophy which makes learning more client and student centred”. This means that not only is access to education made more equitable but also that the experience is more flexible. Fraser and Deane suggest that flexibility in teaching and learning can be provided in a number of ways, which include the resources made available for learning, the interaction between learners, and the support provided for learners. Lewis suggests that changes that would allow a more flexible approach include: improved access to learning resources; provision of flexible student support systems which should include counselling services, bridging, catch-up, remedial and study skills courses; and the development of learning resources and experiences that cater for different learning styles. Lewis also suggests that the educational aim of ‘student-centred learning’ should also be included under the umbrella of flexible learning with the aim of helping individuals take responsibility for their own learning.

In Australia in the 1990s the modern university student has many commitments that impinge on an otherwise full campus life. It is the norm in Australia for students to travel long distances on a daily basis to the campus, and many live on relatively low incomes and have to undertake paid employment in parallel with their studies. There is little Government assistance (AusStudy) available for university students and that is slowly being eroded with increases in the cost of living and decreases in the overall assistance available. In the current economic climate, many students have to juggle university commitments with employment, potentially missing some of the structured teaching and learning sessions and, more importantly, not being able to take advantage of campus-based course materials and face-to-face assistance from staff. A small shift away from courses comprising all face-to-face teaching to courses with more flexible access to teachers and learning materials has the potential to help those very students who may otherwise give up when the pressure of time and other commitments seems too difficult to cope with. McInnis et al found the pressures of part-time work made it extremely difficult for some students to fulfil course expectations. A 1998 survey of first year science students at The University of Sydney showed that 54% of full-time students are undertaking some form of employment, with 31% of all students working 10 hours or more per week during semester, and 14% working over 15 hours per week.

Currently student retention and progression is one of the most pressing concerns for higher education in Australia. McInnis et al, in their Australian benchmark survey of the first year experience, found that over one third of students had seriously considered deferring in the first semester. Their survey showed that the causes for students leaving are many and diverse, including change of intentions, uncertainty of future, other commitments, lack of adjustment, academic difficulty, academic boredom, financial difficulty, and isolation. These are compounded for students who are unable, for various reasons, to take full advantage of what is being offered on campus. Annual national Australian surveys of graduates show that nearly half of those graduating for the first time report that feedback was mostly in terms of marks. Opportunities for helpful feedback on student progress are often limited, and are becoming more limited, as the system becomes more strained, with classes becoming larger, and dollars for teaching becoming more scarce. One way to help solve some of these problems is the judicious use of the Web. On-line materials on the Web: allow for the delivery of course materials in both ‘book’ mode and interactive mode; allow for a means of doing formative and summative assessment; and provide a means of offering asynchronous communication channels for student-student and student-staff interactions. The latter can make a powerful contribution to the student satisfaction equation.

Since the early 1990s, we in First Year Biology at The University of Sydney, along with the rest of the ‘innovators’, have utilised computers in educational settings and this has led to an explosion of material and delivery modes. A discussion of the development and use in First Year Biology of both CAL materials and delivery modes (from stand-alone to Internet-based) can be found in Franklin and Peat and Franklin, Peat, Mackay-Wood and Chambers.

Whilst First Year Biology has for 20 years provided a supervised room for students to access teaching and learning resources, it is only since the rapidly increasing use of the Web that these resources have been moved on-line, and mainly in response to a need to keep the resources room ‘open’ longer. Moving the resources room ‘on-line’ subsequently led to a new focus on communication, offering both a novel email link from students to staff and a mechanism for student-student interaction. In addition this allows the students a flexibility of use that the supervised resources room could never offer.

The web-based communications now available for over 1300 first year students, along with the virtual resources available, can all be accessed via a user-friendly ‘Virtual Resources Room’. These resources are helping to enhance the student experience by providing both an asynchronous communication mechanism for those unable to visit the staff and flexible learning opportunities that help to train students to be independent learners.

Virtual Resources Room

The Virtual Resources Room (VRR) was a web site accessible to all students from anywhere. A new virtual resource centre has recently replaced and enhanced the VRR, to create a better service for the students and to accommodate more courses. The new address is http://fybio.bio.usyd.edu.au/vle/L1/ResourceCentre/. When students enter the VRR (Figure 1) they see a virtual room with all the conventional resource room facilities. It has typical learning equipment such as desks, computers, blackboards, bookshelves and so on, and contains many of the resources that are available from the ‘actual’ resources room. It is an ever evolving web site with new materials being linked in as they become available. The students may see a new ‘shelf’ or other visual aid that will inform them of additional material, along with a flashing
announcement as they enter the site, but the look of the VRR stays the same.

The VRR is available to all users, however students must log in with a User ID and Password to access the lecture note resources.

In the actual resources room materials are located and lent to students by the room attendant, much like in a library. In order to mimic this situation the virtual resources room has been provided with a search engine to enable students to locate materials. The provision of this search engine has also allowed students to locate information more quickly than the actual resources room allows. For example students can search for a particular topic within a lecture, within a first year biology course.

Some general perceptions of the VRR from students via email and open ended questionnaire are:
“It’s an awesome idea”;
“This site is very impressive and better than I could have expected”; and
“… can be accessed at any time from home, night or day”.

Communication via the Virtual Resources Room

Communication between students and staff has traditionally relied on face-to-face meetings. Electronic asynchronous modes of communication are, of necessity, becoming more popular. The two modes we have introduced so far are an email link to staff and a means for students to talk to one another.

CyberTutor

CyberTutor offers students a means of communicating with staff. Students who have an email account can send messages to staff to ask questions about the course content and organisation. Staff check the CyberTutor email inbox and reply to any questions, usually within a day or two. Students are advised that questions need to be specific and not require long detailed answers. If the question is too broad or will require a long answer they may not get the answer they want or the CyberTutor will recommend they come in for a face-to-face consultation. If CyberTutor cannot answer student questions on the lecture material then the email is sent on to the relevant lecturer with a ‘cc’ to the student so that they know where their question has gone. The staff remain anonymous in this process, allowing for the involvement of several staff acting as CyberTutor during the course of the semester.

Discussion group

A discussion forum is set up for student use. This encourages students to access each other in real or virtual time, and allows students to post questions or discuss any topic with their peers. Students can either join a topic currently under discussion or start a new topic for discussion. Each topic under discussion, highlighted in blue, is followed by the date and time of the last posting. Students can click on a topic to check out what has been discussed and follow-up with comments of their own. The discussion area is not routinely monitored by First Year Biology staff.

On-line teaching and learning materials

The development of a web site for student use has enabled students to access resources, including copies of traditional paper-based materials, CAL modules, formative ‘examinations’ and remedial materials linked to the formative examinations, at any time of the day and from anywhere.

Paper-based materials

Course timetables, handouts associated with both the lectures and laboratory sessions, and lecture notes are all available in the VRR. Handouts include electronic versions of all the paper-based materials available in the actual resources room, such as answers to homework and self test quiz questions, copies of the sample examination papers for the various courses and materials required for assignments. Lecture notes (Figure 2) are posted on the Web after the lecture has been given. The format varies from lecturer to lecturer: some are full transcripts; some are in point form only; and some are interspersed with questions. Lecture notes on the Web are not intended to be used as a substitute
for attending the lectures as not all the details or visual aids (slides, transparencies) are included, but they are an adjunct for revision. The lecturers’ email addresses are included so the students can contact them directly if they wish. The most frequent, positive perceptions of students, concerning the most useful/worthwhile aspects of the VRR relate to the availability of the lecture notes, allowing them to catch up on missed work.

**Computer based learning material**

Since 1992 three styles of computer based learning modules have been created and evaluated. They are: tutorials, which are designed to be resources for students to use in conjunction with paper-based materials; pre-lab modules, which are introductions to the use of laboratory equipment or procedures allowing students to practise using the equipment on the computer prior to using the laboratory-based equipment; and revision modules, which review practical material (in particular prepared microscope slides) previously seen in the laboratory.

A special form of revision module is called a SAM (Self-Assessment Module) and these SAMs enable students to take a series of formative tests and exercises aimed at helping them monitor their level of understanding of major biological concepts.

**Formative mid-semester examination**

The aim of the formative examination (Figure 3) is to familiarise students with examination format and typical content, give them feedback on their understanding of the course concepts, allow them to take appropriate remedial action if necessary, help them feel less stressed about the end of course examination, and, hopefully, allow them to achieve at a high level in the final course assessment.

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**Mid Course Exam**

**Section A: Multiple Choice Questions.**

12) The following diagram represents the growth of a population under certain circumstances. Why does the curve flatten off?

- a) Resource Limitation
- b) Predation
- c) Fatigue
- d) Parasitism

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**Figure 2.** Example of lecture notes available from the Virtual Resources Room

**Figure 3.** Part of the formative mid-semester examination on the Web
Remedial materials
Students, who believe their performance in the formative mid-semester examination to be less than desired, are encouraged to use web-based remedial materials which are aimed at enhancing understanding of major topic areas covered in the first semester course. The remedial materials comprise: a tutorial; a glossary of terms used for the particular section of the course; and questions (with hints and answers provided). These remedial materials do not cover all the material in the course but have been selected to include the topics considered by staff to be amongst those that students find the most difficult. They can be used by any student but they have been designed specifically for those in greatest need.

Student perceptions of the formative mid-semester examination and remedial materials were generally positive but a number of students experienced difficulties in making the materials run on their computers. In order to run the mid-semester examination it is necessary to download the Shockwave browser plug-in which is available free from the Web. This issue was resolved by placing instructions on the VRR on how to download the Shockwave browser plug-in.

Student usage and perceptions
The effectiveness of the VRR and the materials available within it has been investigated using survey instruments, focus groups and on-line feedback forms. From the formal surveys over 70% of students (n=240) indicated they had used the VRR and 77% of those students rated it as ‘good’ to ‘very good’ for their learning. Of the students who visited the VRR, 6% used the email facility to communicate with staff, 12% used the discussion group to communicate with their colleagues, 47% used the self-assessment modules and 86% used the lecture notes. Students who visited the lecture notes used them for a variety of purposes including reading them only; printing them out; and for catching up on missed materials.

Students are required to mark the formative mid-course examination themselves from either paper-based resources or web-based resources. In 1998 37% of students used the web-based materials, and 34% of students used the web-based remedial tutorial materials to help increase their understanding.

Students also sent unsolicited comments by email on their perceptions of the Virtual Resources Room such as: “Biology web site extremely useful and well organised”; “You have done an absolutely fantastic job ... I appreciate it very much and so do not do many other 'silent' students”; “Overall this message is mainly to compliment the staff on an excellent set of resources and to encourage you to continue developing them”; “In response to the idea for putting the CAL modules on-line. I think it’s a wonderful idea. I can’t express how great I think that idea is ...”; and “Just a note to say thanks. FYB definitely makes more (use) of the on-line resources than most other subjects”.

The positive responses and free-form comments from students indicate that we are making a strategic contribution towards their learning. In time the ‘newness’ of our intervention may reduce the eagerness of their responses but we will still have addressed an access and equity issue.

Discussion
University teaching and student learning are moving through transition processes, driven by many factors including changing student requirements and economic forces. In First Year Biology we have tried to encourage students to develop collaborative learning strategies and we have offered a more flexible delivery for some of our materials, such that our students can choose when they want to be engaged in these activities. To this end we have introduced strategies for setting up learning communities in large classes which include creating small peer working groups; group laboratory experiments, field work and poster presentation; specially designed card and board games; and computer-aided learning materials designed for use in peer groups. It is clear from the student response to surveys that we are using the technology as an adjunct to their learning process, allowing them to learn in a way that suits their lifestyle and which we hope will enhance opportunities for participation in higher education. Moving part of the total course materials to the Web stimulated us to design web-based communication capabilities, as an adjunct to face-to-face contact with students. It is felt that some students may feel more comfortable communicating electronically with staff while others may never use the facility.

In First Year Biology we aim to mix virtual learning on the Internet with real life, face-to-face learning in practicals and lectures, but with an emphasis on accessing virtual learning resources. Using the Web for the delivery of teaching and learning materials has already led to an increase in flexibility for students using the materials. Students now have greater access to the materials than previously as our on-line facility is open 168 hours a week. Depending on their preference, students can now access all our teaching and learning resources either in person by visiting the actual resources room or electronically via the Virtual Resources Room. Thus students without Internet access are not disadvantaged. In time the traditional three lectures a week and three hours of laboratory work will diffuse into a mix of these styles with small group activities and independent activities associated with computer-aided materials, with a greater emphasis on student autonomy within the learning process.

Moving the materials onto the Web is in line with The University of Sydney, Faculty of Science policy on equity of access and availability of teaching materials. Access has been greatly enhanced by the opening of student computer laboratories (one with 24 hour a day access) across the University campus. This has enabled students without home-based computers, who previously may have been disadvantaged, to have 24 hour access to the Web. In 1998, a survey of first year biology students at The University of Sydney showed that 89% of students have computers at home, but only 54% of students with computers at home
are linked to the Internet. However, 62% of those students without the Internet at home use networked computers provided on campus to access the Virtual Resources Room. Another 10% of students access the Internet in the resources room. It is assumed that the number of students with Internet access at home will increase each year. Australian Bureau of Statistics\(^2\) data show that the number of Australians with the Internet at home has quadrupled in the past two years. These data show that 250,000 homes were connected to the Internet in 1996, with this number increasing at a steady rate to 1.038 million in 1998. It is assumed that this will be reflected in increasing numbers of first year biology students with Internet access at home.

Presenting materials in this non-confrontational, user-friendly way offers students the benefits of different learning modes, depending on their preferences. They can test themselves using self-assessment packages; they can read lectures they may have missed; and if they want to interact with other students or staff, they can use the discussion group or CyberTutor. All of these activities puts the onus on the students to take responsibility for their own learning, but in a way which caters for all learning styles. The students have indicated their appreciation of our efforts and have, through the use of CyberTutor, given us many ideas for further improvements. Thus we are moving towards a closer partnership with our students in these endeavours.

“To produce graduates equipped for the workplace, it is essential that educators teach in ways that encourage the learner to engage in deep or meaningful learning, which may be built on in the later years of their course, and also be transferred to the workplace.”\(^3\)

In the next few years we will need to develop a more powerful measure, or sets of measures, to evaluate the strengths and weaknesses of both the mix of on-line and face-to-face teaching experiences. The next few years will show us the ways in which students will want to learn and communicate with staff and with other students and we need to be flexible in accommodating their preferred learning strategies.

Acknowledgements

The author would like to thank Sue Franklin for being committed to improving student learning; Rob Mackay-Wood for his continued enthusiastic programming of the student materials; and Professor Robert G. Hewitt who, as Dean of Science 1988-1999, has been pivotal in the support of teaching development within the Faculty of Science at The University of Sydney.

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CAL-laborate, June 2000
Virtual reality displays of haptic information may force a rethink about the nature of touch, and the importance of externalization for perceptual realism. Also, a closer look at externalization may cast some light on the basis of self-awareness.

The race is on to find ways of delivering virtual touch. Virtual reality systems have so far concentrated on vision and hearing but some set-ups now include sensors on gloves that allow monitoring of movements, and possibly some production of movements. There are also some systems that, with feedback from remote sites, allow surgery across thousands of miles via telerobotics. One such system is based in Perth and was recently demonstrated to Queen Elizabeth II. She was reportedly “amazed”. However, there is a long way to go before she or any of us can enjoy the experiences available on the hollidecks of Federation starships depicted in the TV series *Star Trek*.

Impressive as some virtual reality systems are with respect to vision and hearing, creating virtual touch is a challenge we have hardly begun to face. We don’t even agree on what touch is. Some of us use the word to include only the skin (cutaneous) sensations such as pressure, shear, tickle, itch, temperature change, and chemical reactions. Others include in touch the position senses of kinesthesis and proprioception, which terms are themselves used to mean different things by different people.

To achieve realism in a virtual system we shall need to capture all the interacting features of our senses, regardless of what we call them. In view of this, I will sidestep labelling issues for now and use the term ‘haptics’ to cover all senses to do with the reception or production of cutaneous and movement/position information.

What determines how real a percept is? One feature important for realism is common to all senses and is called *externalization*.

**Externalization of percepts**

No aspect of perception is more remarkable than our ability to perceive objects and events as ‘out there’, remote from us, or distal. This trick works despite having to depend on receptors that are well and truly proximal.

The surface of the human eye’s retina is curved like the inside of a tennis ball but this is not what gives rise to our perception of the visual world as being three-dimensional. The image on the retina, called the *proximal* stimulus, is two-dimensional and we rely on a large number of binocular and monocular cues to interpret this essentially ‘flat’ display as having depth, and containing information about *distal* objects. Externalization is based on inferences drawn from the proximal stimulus display, though it may be that the senses have to work together to achieve this.

A few years ago it was suggested that auditory externalization relies on vision (Bartley, 1969). We now know that in a free field, in contrast to sound delivered via headphones, we externalize sounds rather than perceive them as located in our ears or inside our heads. This is possible, not only because we have two ears and can use inter-aural differences to help make directional and distance judgements, but because our pinnae change the frequency-amplitude profiles of sounds before they impinge on the eardrum. It has been shown recently that these pinna cues are extraordinarily important in providing a sense of true auditory three-dimensional space (Middlebrooks and Green, 1991).

What about touch? When you feel for coins in a pocket or purse, are you externalizing the tactile stimuli or does the skin only perceive proximally? Most
psychologists readily classify vision and hearing as ‘far’ senses – those that perceive distal stimuli, but touch is often referred to as a ‘near’ or proximal sense, as are the senses of taste and smell. Yet isn’t that nasty smell distally attributed, rather than sensed in the nostrils as a state of olfactory receptors? And when we taste food, are we not very much aware of texture and temperature as qualities it possesses in contrast to, for example, the temperature and texture of the tongue? These questions remain for debate but with regard to the skin, it does not follow that because tactile stimuli actually contact the skin, the percept must be proximal.

Firstly, we do not pay attention to our receptor states when feeling, any more than we do when seeing or hearing. Our attention is generally directed to the object we are touching or being touched by. This is obvious when we explore an object not with bare fingers, but with a probe such as a white cane, as used by the blind. We build up a percept of the texture or object at the exploring tip of the cane, not at the handle end and not by noting changes in the states of receptors under our skin touching the handle of the cane, although these changes are the information upon which externalization depends. Kennedy, Richardson and Magee (1980) argued that one thing we ‘feel’ when riding a bicycle is the surface of the road, as a distal stimulus. This is distinct from the handlebars and saddle, through which information about the road surface is obviously transmitted, and which feel more proximal than the road, but also are distal, in the sense of being external to us. The road’s visual texture combines with haptic information and may assist externalization.

Secondly, it has been reported that when hearing is masked and changes in vibration at two fingertips signal movements of a sound in space, the tactile percept seems to move across the space between the fingertips in a manner analogous to visual phi phenomena (Gescheider, 1980). Such sound-to-touch transforms may also be perceived as stationary in space (Richardson, 1990). More dramatically, researchers at the Smith Kettlewell Institute of Visual Sciences tested a blind subject who reported an object not with bare fingers, but with a probe such as a white cane, as used by the blind. They digitally recorded an active subject’s movements in the X-Y plane and then uses motors to guide passive subjects over a pathway identical to that followed by the active explorer. Meaningful active-passive comparisons are made possible with this system as are systematic measures of the importance of components of haptic exploration (e.g. pressure, shear and kinesthesia).

Few researchers would have expected active exploration to be worse than passively guided exploration yet this was reported when the task was to identify a raised line drawing using a single fingertip (Magee and Kennedy, 1981; Richardson, Symmons and Kennedy, 1998). One difficulty in interpreting such results has been lack of assurance that the exploratory movements of passive and active subject are really identical (matched) and that the only difference in experience is the active versus passive conditions of the independent variable.

This difficulty has been overcome with a device called the Tactile Display System (Richardson and Symmons, 2000), which digitally records an active subject’s movements in the X-Y plane and provides active and passive-guided movement of that fingertip over a raised line drawing was present. Preliminary results with these two systems are in agreement in some respect e.g. a surprising amount of shape information can be gleaned from a line moved under a stationary fingertip, in contrast to free movement of that fingertip over the drawing. However, passive-guided superiority has been confirmed only with the Tactile Display System. It is hoped that more can be learned about haptics by comparing results with these two kinds of display, one real and the other virtual.

Three dimensional virtual objects in haptic space

While research continues on haptic perception of two-dimensional displays, other work uses a probe to simulate the haptic exploration of different surface textures, and three-dimensional solid objects. SensAble Technologies (http://www.sensable.com/) have produced a device called the PHANTOM which consists of a rod-like probe, linked at joints and free to move in various directions within a limited space. By manually exploring with this probe, a user can feel resistance at certain places as if a solid object
CAL-laborate, June 2000

is present. In fact, however, a computer is programmed to create such resistance according to the virtual object selected for haptic display. This is a compelling demonstration that a tactual object does not even have to exist in order to be perceived and externalized.

Current applications of the PHANTOM include practice at assembling and manipulating parts, telerobotics, training of skills such as surgical techniques, and human factors research. With only a single ‘point of contact’ this is a very rudimentary system that does not do justice to the richness of normal haptic experience. However, the fact that telecommunication companies (e.g. British Telecom) are working on similar systems with a view to commercial applications suggests that progress in haptic research is likely to proceed at a rapid pace.

Self-awareness

Externalization is surely important for a sense of realism and it is real objects or stimulus events of which we are conscious when we perceive. We must attribute the source of stimulation to distal locations for to do otherwise would mean being body-bound and uninformed about the world around us. This may not matter for clams which react automatically to possible predators and gather sustenance from the water surrounding them. This would seem to justify the suggestions that clams lack self-awareness just as we are unaware of the physiological processes that underlie our perceptions. When we perceive, some very clever automatic processes swing into action and do most of the complicated work with our (selves) knowing little or nothing about them. The end result of these parallel and unconscious physiological processes is the conscious percept.

How these processes develop in our early years is still largely a mystery but it does not seem impossible for there to be a link between externalization and self-awareness. Might this be nothing more than the inevitable consequence of first having externalized objects, and then having noticed that among them is a special one called ‘self’? This would not be an abrupt discovery occurring on the way to work one day, but a gradual appreciation of which externalized objects belong to self, and which to others. An example of something along these lines might be seen when a child at first tracks their own hand-movements (as if surprised and unable to anticipate these movements), but then comes to realize that he/she is in control of the hand and can now correlate the haptic and visual experiences. A similar self-awareness may be demonstrated by dogs when they stop chasing their own tails.

If this reasoning is correct, it follows that self-awareness is not a peculiarly human characteristic but an attribute of any organism, or machine, capable of perceiving objects as distal and then perceiving itself as a special case among these objects. This reasoning, in turn, leads to the suggestion that robots can become not only conscious (with this being verifiable according to the same criteria we use to declare humans as conscious) but self-aware.

It seems clear that externalization is a necessary condition for self-awareness, for without it we would not know of a world of distal objects at all. However, the suggestion here is that it is also a sufficient condition for self-awareness. Sufficiency can be argued because it is inevitable that, as we move through infancy, we will encounter bits of ourselves among externalized objects and will ultimately integrate these into an object (self) that is distinct from all other objects. When this integration is complete, we may be said to be self-aware.

In conclusion, it seems possible that the attempt to produce a convincing haptic virtual display will lay to rest the mistaken view that touch is not a distal sense. In addition, it is possible that the process of externalization can account for self-awareness.

References


The Use of Communications and Information Technology to Support Small-group Teaching Activities in Psychology

In this article we discuss with examples ways in which Communications and Information Technology (C&IT) can support small-group activities in Higher Education with a main focus on psychology. Identification of the range of C&IT used to support small-group activities will not only illustrate how educational objectives traditionally associated with seminars and tutorials can continue to be met even when class sizes increase but also provide exemplars of educational innovation within this area.

The findings reported here are based on the work of the ASTER (Assisting Small-group Teaching through Electronic Resources) project which is led by The University of York with project partners at the University of Oxford, University College Northampton and the University of Surrey and funded under the UK Higher Education Funding Council for England (HEFCE) TLTP3 programme. The project aims to explore how communication and information technologies (C&IT) can assist students and lecturers in making the most effective use of small-group learning and teaching. The discipline areas investigated include psychology, physics and a variety of disciplines from the humanities.

The variety of C&IT in small-group teaching and learning

Researchers and practitioners tend to give different reasons for justifying the introduction of C&IT into small-group teaching. The rationale cited in the research literature is often stated in pedagogic terms, such as ‘to facilitate deep-learning’, ‘to practice problem-solving’ and ‘to develop critical thinking skills’. These aims are met by objectives such as ‘encouraging and increasing participation’ and fulfilled by students engaging in tasks that facilitate discussion and writing. Providing transferable skills and finding practical solutions to maintaining small-group teaching in the face of larger class sizes are also cited. Authors that explicitly state models of learning tend to use constructivist or social context models with an emphasis on student-led approaches.

In practice, the 41 lecturers interviewed for the ASTER survey (Trapp et al, 1999) focussed on pragmatic reasons for introducing C&IT: large class size; providing improved resources; facilitating discussion; increasing student involvement and interest; keeping students on-task; providing more consistency and fairness; quicker feedback; flexibility of time management; increasing discussion opportunities; making courses more interesting; and improved contact time.

A simple way of classifying the use of C&IT to support small-group activities is in terms of providing content, of supporting the learning process and of managing course administration. Examples from psychology that fit into these categories are listed in Table 1. Full descriptions of these examples based on interviews with students and lecturers can be found on the ASTER web site at http://ctipsy.york.ac.uk/aster/.

C&IT can provide content

C&IT is an important provider of course content in the form of source material, tutor notes, worksheets, case studies, support materials, data, web resources and tutorial software. These may be used by students as background prior to classes, to provide examples and discussion material during a small-group session or for information or remediation after formal lessons.

With increasing student numbers, small-group teaching sessions are an
Table 1. Summary of uses of the Web from ASTER case studies

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<thead>
<tr>
<th>Category</th>
<th>Use</th>
<th>Brief description</th>
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<tbody>
<tr>
<td>Content provision</td>
<td>Course delivery</td>
<td>Complete course on the Web</td>
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<td></td>
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<td>Email delivery of material replaces lectures</td>
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<td></td>
<td></td>
<td>Convert lectures to multimedia for web delivery</td>
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<td>Supporting the learning process through construction and integration</td>
<td>Explore examples</td>
<td>Web multimedia clips of developmental and social behaviour</td>
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<td></td>
<td>Support for lectures</td>
<td>Overheads and exercises on the Web</td>
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<td>Provision of internal (e.g. course notes) and external (e.g. support materials for course texts)</td>
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<td>Demonstrations and simulations adapted for the Web</td>
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<td>Email used to deliver support materials</td>
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<td>Lecture handouts and old examination papers on the Web</td>
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<td>Web resources to support research methods course</td>
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<td>Student projects</td>
<td>Software used for demonstration purposes earlier in course is subsequently used for project work</td>
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<tr>
<td>Use in laboratory practicals</td>
<td>Web clips used in laboratory on observational methods</td>
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<td></td>
<td>Remote access to analysis packages</td>
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<tr>
<td>Assessment</td>
<td>Web-based multiple choice test with feedback</td>
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<tr>
<td>Supporting the learning process through dialogue</td>
<td>Communication</td>
<td>Group tutorials on the Web, with email question and answer sessions</td>
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<td>One-to-one student-tutor discussion</td>
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<td>Students ask questions over email</td>
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<td></td>
<td>Communication plus resources</td>
<td>Use of simulated environment (MOO) for seminar, with resources, assignments, discussion facilities</td>
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<td></td>
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<td>Email dialogue with tutor and FAQ list integrated with support resources for research methods course</td>
</tr>
<tr>
<td>Preparing for face-to-face</td>
<td>Email used to circulate information and instructions about tutorial sessions</td>
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<tr>
<td>Course administration</td>
<td>For lecturers</td>
<td>Web-based communications software used by faculty and administration staff for management of teaching</td>
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<tr>
<td></td>
<td></td>
<td>The accumulation of a large corpus of departmental web resources enables tutors to assemble components into support materials for their courses</td>
</tr>
<tr>
<td></td>
<td>For students</td>
<td>Web pages contain information and resources for course as a whole and specific modules</td>
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<tr>
<td></td>
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<td>Use of email to distribute general course information</td>
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<td>Handbooks, timetables on the Web</td>
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Cal-laborate, June 2000

expensive form of learning and so it makes sense for staff and departments to ensure that when small-group teaching does happen it is as effective as possible. Allowing students to have access to content materials prior to a seminar or tutorial can shift the balance of activities that take place during the session towards more discussion and interactive work. One example of this approach includes the provision of resources on the Web prior to the seminar thereby allowing the seminar to focus entirely on integration and application of knowledge using case studies and discussion questions. Another example is where the Web is used not to support dialogue directly but to provide materials and instructions to ensure that all students are ‘up to speed’ prior to a face-to-face meeting. In this example the Web is used to make available summaries of papers by students which all members of the group are required to read before the face-to-face session.

C&IT can support the learning process

Mayes (1995) has proposed a simple framework for considering the stages or processes that a learner typically passes through in a learning cycle of gaining understanding of a topic. Mayes’ framework is based in part on Rumelhart and Norman’s (1978) description of three modes of learning: structuring (involving the formation of new schemata); accretion (adding new knowledge to existing schemata); and tuning (the fine adjustment of knowledge to the demands which are made of it). According to this framework, once the learner has acquired some basic knowledge of the topic, they move into the construction stage, and start to interpret this knowledge in terms of their prior knowledge and their particular goals and motivations, and linking and classifying information in new ways; in short, to build up personal meanings. This construction process may be helped through tools to select, analyse and explore such as simulation, multimedia, assessment and reflective software.

The use of simulations to increase understanding of dynamic and complex processes can be found in psychology. Both Morris (1998) and Cumming and Thomason (1995) describe the use of simulations to correct common misconceptions in understanding statistics. An example of this type, SPEED (Hammond and Askins, 1999), is illustrated in Figure 1. Another simulation found
in psychology is the COR software used to teach observational research.

Figure 1. SPEED: a computer-based tutorial on correlation and regression (Hammond and Askins, 1999)

The use of videos to support small-group teaching is well known. Dequeker and Jaspaert (1998) report on 20 years’ experience with video-supported small-group learning for problem solving and clinical reasoning. The ability to incorporate video clips into software or web resources allows more opportunity for them to be integrated into small-group activities. Multimedia software can therefore provide a dynamic medium to support the construction and integration of knowledge. Examples within psychology include students exploring multimedia clips on developmental and social behavior in preparation for a discussion in class.

According to the Mayes model, the learner benefits from reflecting upon, sharing and discussing his or her understanding. The understanding has reached a point where key concepts can be articulated, evaluated and refined both through self-reflection and discussion with others. This process (and indeed the construction process) may lead to the formulation of new questions or the identification of further issues for study, thus closing the loop.

The use of the Web to support dialogue processes in learning falls into three types of usage: preparing students for later face-to-face communication; the use of the Internet for either one-to-one or group discussion; and an elaboration of this where contributors share electronic resources over which discussion may be focussed. At the simplest level the use of email provides a convenient method of communication with which the student has time to compose the question or comment (without having to wait for the tutor to be available) and the tutor can answer at a convenient time and with a due level of reflection.

There are examples of materials created by psychology students available on the Web, such as at Miami University’s Psybersite which provides a gateway to web tutorials on a variety of topics in the field of psychology. All of the educational modules at this site have been created by advanced undergraduate and graduate students at Miami University. These activities were designed to increase student motivation and encourage active involvement as described by Sherman (1998).

So far in ASTER’s work we have not found examples of the use of specific facilities to aid the construction of ‘personal representation’, such as concept mapping tools. This is not to say that such learning activities do not take place, but if they do they are relatively rare.

An interesting use of software to support peer-based tutorials is reported by Tolmie and Anderson (1998). The software helps to pace students through consideration of various aspects of their project design procedure. There are three two-hour sessions in total, undertaken by groups of 3-4 students working on related topics. In each session, the software proceeds by identifying key issues and asking the group to discuss these as they apply to each student’s project in turn. The reflection stimulated by this discussion is then consolidated into firm decisions through report-back sessions with supervisors.

Within psychology we found examples of lecturers introducing C&IT in order to provide rapid feedback to students on assessment tasks such as self-study worksheets. On one course, assessment of practical work formerly marked by a team of postgraduates had been replaced by automated assessment in order to obtain more consistent marking. Formative self-assessment can be popular with students and many publishers now provide formative self-assessment resources over the Web.

C&IT can help with the organisation and administration of courses

Electronic resources can assist with course organisation by facilitating dissemination of relevant information and communication with students. There is no doubt that introducing C&IT can create a more flexible learning environment for students who might have difficulty fitting in with a traditional campus-based timetable. For example, group project meetings conducted electronically mean that students can communicate without space or time restrictions.

Virtual learning environments can also provide a structure for group members’ participation as well as providing clear demarcations of the individual group members’ contributions.

With increasing constraints on staff time and flexibility of course structure, the use of C&IT in small groups can provide students with opportunities to practice skills without increasing the teaching load on staff. Video-conferencing provides another potential time-saver by enabling students to have lessons with staff based in different institutions.

Conclusion

The simple framework provided here has allowed us to categorise a broad range of ways in which C&IT is being
used to support small-group activities within psychology. We hope that the examples will provide ideas that can be used and modified by other lecturers to enrich and support small-group activities on their courses.

References


Miami University’s Psybersite http://miavx1.muohio.edu/~psybersite/


http://cti-psy.york.ac.uk/aster/publications/asterm1.pdf


http://cti-psy.york.ac.uk/aster/publications/ Report_2/ report_2.html

A Metabolic Challenge on CD-ROM

Abstract

We have introduced a novel approach to the learning of metabolism by undergraduate students of biochemistry by providing them, on CD-ROM, with an intellectual challenge relating to ‘real world’ metabolic problems.

The CD-ROM Biochemistry – A Metabolic Challenge is an integral component of our course curriculum but has been introduced with different emphasis into the different undergraduate Biochemistry courses. For science students, the programs are an adjunct to formal lectures and part of problem-solving sessions that are a component of the practical classes. For biomedical and medical students, who are high academic achievers, the CD-ROM is also used for self-directed learning and case studies whereby students are expected to take more responsibility for their own learning.

The problem-solving exercises, entitled The Great Metabolic Race and The After Race Banquet, explore the metabolic changes that occur to an athlete during a long distance race, and the subsequent recovery phase. The exercises are question/problem based and interactive, requiring students to analyse the questions, think logically and respond by integrating information drawn from a variety of sources. A set of thirteen self-paced, interactive tutorials covering the fundamentals of metabolism are linked to these exercises to act as one resource. While the answers to the questions do not appear in the tutorials, the information required to formulate the answers does. The CD-ROM is used for self-directed learning to help students visualize pathways and the relationship between them, and to integrate the knowledge they have acquired from various sources. It also contains case studies to teach students how these pathways are affected in specific clinical cases.
Surveys have shown that students respond particularly well to the participatory nature of this new resource and find the self-paced learning and testing very valuable. We also have preliminary indications that the use of these programs does translate into improved student comprehension as judged by examination performance.

Introduction

Biochemistry is a very broad and complex discipline, knowledge of which requires the ability to integrate a wide range of concepts. It is a challenge to teach students, especially in large classes, how to acquire this skill. This can be partly overcome using computer-aided programs which provide a highly flexible way to deliver difficult material and enable students to learn at their own pace, in their own time.

Most computer programs developed in the field of biochemistry to date are either aimed at school leavers, or cover a very specific topic (e.g. enzyme kinetics). The CD-ROM entitled *Biochemistry – A Metabolic Challenge* is more broad ranging and has been developed with the aim of teaching the principles of metabolism to a variety of university undergraduates including science, biomedical and medical students.

The package also forms the basis of a non-traditional and very flexible approach to the acquisition and development of learning skills; it is used as the focus for both problem-solving exercises and case study related self-directed learning, as well as being a resource for information, revision and self-assessment. In a teaching sense, the package is utilised in different ways depending on the prior knowledge of the students, the objectives of the particular course and the size of the class.

Description of the CD-ROM

The CD-ROM contains two interactive self-paced exercises, *The Great Metabolic Race* and *The After Race Banquet* (Figure 1).

These exercises relate specifically to the catabolic metabolism associated with long distance running and the anabolic metabolism associated with the recovery phase. They test the students’ ability to integrate and understand concepts and pathways that are often learned in isolation. The exercises involve true/false questions, multiple choice questions, ‘click and drag’ question and answers and calculations, the results of which are scored by the computer.

A series of quite extensive self-paced interactive tutorials and activities on various aspects of metabolism accompany and are linked to these exercises (Figure 1). The tutorials use animated demonstrations, ‘click and drag’ reaction sequences, ‘click and drag’ question and answers and multiple choice extension questions. The tutorials serve as an information resource and the information within them can be readily accessed through a comprehensive index of topics, even while undertaking the exercises.

Application of the CD-ROM to teaching/learning

The flexibility of the package is reflected in the ways in which it has been used, both within a structured teaching environment and by the students in their own time. Our experience relates to the teaching of three separate groups of undergraduate students, all doing biochemistry as a discrete discipline for the first time, namely science, biomedical and medical students. Our utilisation of the package has varied depending on the course being taught: the science students using a combination of formal lectures and problem-solving exercises while the biomedical and medical students use a more case related self-directed learning (SDL) approach with a lesser emphasis on formal lectures.

Students in all courses use the programs extensively for revision and self-assessment purposes.

Science students

Science students constitute a large group of approximately 250-300 students. They come from very diverse academic backgrounds and include students doing double degrees such as Arts/Science and Science/Law – some have had a lot of chemistry and biology, others very little. They also represent a broad range of academic abilities.
For these students, the lecture programme on metabolism spans a 13 weeks period and presents core information. The CD-ROM is often used within the lectures for illustrative purposes and for the animated demonstration of difficult concepts such as electron transport – see Figure 2.

Students learn to interpret a graph (Figure 4) illustrating the changing dependence on carbohydrates and fats as energy sources throughout the run and monitor their knowledge through a series of questions which are linked to the tutorials.

Student performance in this exercise is scored by the computer and provides useful information about their level of understanding.

The problem-solving exercises, which rely extensively on the use of the CD-ROM, are an adjunct to the formal programme of lectures and form an integral part of the practical course as outlined in Table 1.

<table>
<thead>
<tr>
<th>Lectures on Carbohydrate Catabolism</th>
<th>3 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem-solving exercise: The Great Metabolic Race</td>
<td>4 hours minimum</td>
</tr>
<tr>
<td>Follow up tutorial on problem-solving exercise</td>
<td>1 hour</td>
</tr>
</tbody>
</table>

Table 1. A science student’s typical weekly timetable

In the problem-solving exercise session mentioned in Table 1 students are required to work through the exercise The Great Metabolic Race (Figure 3). In this exercise the metabolic activity of a distance runner is monitored at various time intervals to give practical examples of how the body generates energy from the catabolism of various macromolecules.

In one such question screen, for example (Figure 5(a)), a student who is unsure about the pathways used by the muscle to produce acetyl-CoA for energy generation can obtain assistance from the tutorials using the Index link as shown in Figure 5(b). In this example, the student can click on ‘Muscle’ in the Index, followed by ‘Pathways Utilised by’ to find the required information as shown in Figure 5(c). In this manner, students must think logically about how to find the information rather than being led directly to it using hyperlinks.
On completion of the exercise, students are asked to write an essay of approximately 1000 words to consolidate what they have learned. The essays are discussed in a small group setting with the tutors once they have been corrected.

**Biomedical and medical students**

Biomedical and medical students constitute two separate groups each of approximately 160-200 students. They tend to be less diverse in their background and generally have a good grounding in chemistry or biology or both. Course entry requirements dictate that they are high academic achievers and generally very highly motivated. The depth of knowledge required in biochemistry is not as great for the medical students as for the science or biomedical students and the emphasis is somewhat more clinical. The course component on metabolism is taught over a period of 10 weeks for medical students and 14 weeks (spread over two years) for biomedical students.

In order to stimulate and challenge these students we have adopted a much more self-directed learning approach whereby students are expected to analyse problems, locate relevant source material and develop habits of independent study. As indicated in Table 2, there is a reduced core of basic lectures, supplemented with SDL tasks that are largely case study based.

Case studies are conducted in small tutorial groups (approximately 10 students) which meet for approximately 3-4 hours (Table 2). Students are expected to prepare for the tutorial in their own time and are responsible for the running of the tutorial. The tutors act merely as facilitators.

### Table 2. A medical student’s typical weekly timetable

<table>
<thead>
<tr>
<th>Lectures on Carbohydrate Catabolism</th>
<th>2 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Directed Learning: “Tissue Metabolism- How do skeletal muscles convert energy stored into mechanical movement?”</td>
<td>1 hour minimum</td>
</tr>
<tr>
<td>Case-study: ‘Alcohol Metabolism’</td>
<td>3-4 hours</td>
</tr>
<tr>
<td>Follow up tutorial on SDL</td>
<td>1 hour</td>
</tr>
</tbody>
</table>

Students experience great difficulties in integrating concepts taught at different stages of the course, generally by different lecturers. SDL using computer programs and case studies are excellent tools to help overcome these difficulties.

In the SDL example used here, students are asked to look at the metabolism of macromolecules by skeletal muscles in various energy states and to correlate the events occurring in the muscles with those in other tissues/organs. Students can test their progress by using multiple choice questions that accompany most screens.

During a case study on ‘Alcohol Metabolism’, students extend their knowledge on ‘Tissue Metabolism’ by looking at the effects of alcohol on the general pathways. Case studies are held as paper exercises but accompanying computer programs again facilitate the students’ task in visualizing and integrating pathways.

As hinted at in Figure 7(a), the NADH/NAD⁺ ratio is sensitive to alcohol and students need to explore why this is so, and identify which of the pathways will be affected by changes in this ratio. One example of a relevant pathway is...
given in Figure 7(b). Only then can the student begin to deduce the impact of excess alcohol on the liver.

**Figure 7(a).** NADH/NAD⁺ sensitive pathways (from the case study on Alcohol Metabolism)

**Figure 7(b).** One of the pathways which can be affected by over-consumption of alcohol (from the tutorial Biosynthesis of Carbohydrates)

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### Evaluation of the CD-ROM's educational value

Response to surveys conducted with science students (250), biomedical (150) and medical students (160) indicated that 90% of students gave a score of 4/5 or above in terms of improving their understanding of the subject. The same percentage of students preferred this Problem-Based Learning approach to the more traditional didactic teaching. Although not all programs on the CD-ROM were part of a compulsory exercise, the survey showed that over 50% of the students had worked through all of these exercises.

It is felt that students’ performance in essay writing has improved since the introduction of the CD-ROM into the biochemistry course and continuous feedback from the students has indicated how much more enjoyable and rewarding the learning of biochemistry has become.

A recent survey conducted with medical students who participated in the Self-Directed Learning sessions indicated that this mode of learning is preferable even though it is considerably more time consuming for students. SDL is also more time consuming for staff as followup tutorials are conducted in small groups requiring several staff members to be conversant with the topics.


### Acknowledgments

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This newsletter was brought to you by:

**UniServe Science**

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The activities of **UniServe Science** include:
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- disseminating all this information, by newsletters and electronic means;
- maintaining a web-based searchable database of information about teaching software;
- maintaining a web site which also includes information about discipline-specific teaching resources and links to other relevant sites;
- organizing to get new packages reviewed by teaching academics, and making these opinions available;
- setting up other exchanges of information by means of the Internet;
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**BioQUEST Curriculum Consortium**

The **BioQUEST Curriculum Consortium** was founded in 1986 by Professors John Jungck and Nils Peterson and is headquartered at Beloit College via a commitment to the Annenberg Fund of the Corporation for Public Broadcasting, the first major funder of the **BioQUEST Curriculum Consortium**. BioQUEST has been self-sustaining in its operations through the support of two major foundations, the Howard Hughes Medical Institute and the National Science Foundation. Current funding extends to 2004.

The **BioQUEST Curriculum Consortium** supports and encourages innovation in bioscience education through the development, distribution, and field testing of computer based curricular materials that have been designed to help students learn long-term strategies of research. BioQUEST is an acronym for *Quality Undergraduate Educational Simulations and Tools in Biology*, reflecting its initial focus on the development of curricular resources for biology educators through The BioQUEST Library. The Curriculum Consortium emphasizes investigatory and collaborative learning strategies for problem solving in the biological sciences. To these ends, workshops for faculty development, multiple presentations, and publications by staff and collaborators are provided each year. A communication network for committed educators is maintained by the organization.


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**Learning and Teaching Support Network**

The **LTSN** has been established by the UK higher education funding bodies to promote high quality learning and teaching in all subject disciplines in higher education. The network supports the sharing of innovation and good practices in learning and teaching including the use, where appropriate, of communications and information technology.

The network consists of:
- 24 subject centres;
- a Generic Learning and Teaching Centre; and
- a programme director and co-ordinator.

Many of the new subject centres build on existing Computers in Teaching Initiative (CTI) centres and involve learning and teaching support networks created by other funding council initiatives, such as the Fund for the Development of Teaching and Learning (FDTL). The new centres will become the main points of contact within subject communities for information and advice on good practices and innovations in learning, teaching and assessment, and will provide support for the many networks which already exist.

The GLTC will provide strategic advice to the sector on generic learning and teaching issues, disseminate good practice in the development and deployment of new methods and new technologies, and act as a knowledge broker for innovation in learning and teaching.

[http://www.ltsn.ac.uk/](http://www.ltsn.ac.uk/)