

CAL-laborate

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

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tertiary level physical sciences

October 1998



CTI Centres for Physics,
Chemistry and Maths
United Kingdom



UniServe Science
Australia



Council for the Renewal of
Undergraduate Education
Sweden

Editorial

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 also because the content of what is taught also needs to be customized for local markets — where you live cannot help influencing what you need to know. Within this context we are very pleased to publish this second CAL-laborate newsletter in Australia, Sweden and the United Kingdom.

There have been many changes since CAL-laborate 1997 was published. The most obvious is the adoption of the World Wide Web by teachers everywhere. What was merely an interesting new toy just a few years back, is now the great white hope for the future. Enthusiastic teachers are convinced that it will increase the effectiveness of what they are doing. Administrators are convinced that it will increase cost efficiency. And there are signs, from a recent survey in Australia, commissioned by the Committee for the Advancement of University Teaching, that both sides may be justified, at least to some extent.

There are several areas in which especially good work is being done all round the world. One is in the area of computer based assessment. There are now quite a few commercial systems, and many more “home grown” ones, to choose from, some of which use the World Wide Web as a delivery tool. Three of the articles in this newsletter feature examples of these. Various attempts have been made over the years to set up data banks of questions to go with these assessment packages, and there have been some successes. This is an area where cooperation between teachers, institutions and countries will surely prove fruitful. If you are interested in becoming involved in such an activity, please contact one of the collaborating organisations.

Advances are also being made in the area of student-teacher and student-student interaction via the web. Again one of our articles deals with this topic. If ever some kind of flexible, computer based instruction (with or without the web) is to become an important part of our teaching, so that it replaces some of the face-to-face lecturing, tutoring, demonstrating that we currently do, we need to keep our eye very firmly on the trial projects that are being done right now, and share information about the outcome of those trials.

The other four articles describe various teaching packages, in chemistry, mathematics and physics. Although some of these have been available for some time, they are still not used as widely as they might be within standard courses throughout science disciplines. The fundamental requirements for the routine use of computers in science teaching are still elusive, as are the benefits that have been promised for so many years. Here too is an area where we can only keep trying to promote cooperation.

The web has enormously increased our ability to communicate with one another, without necessarily making any clearer what we should be communicating about. In our job of teaching university science there is still a very obvious need to collaborate with one another, irrespective of what country we live and work in. We should use the increased communication capabilities of the web to make that cooperation more effective. The publication of the second issue of CAL-laborate is therefore a symbol of our belief in that ideal.

Dick Bacon

Hans Jalling

Ian Johnston

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Editors:

Anne Fernandez
UniServe Science
Carslaw Building (F07)
The University of Sydney
NSW 2006
Australia
PhySciCH@mail.usyd.edu.au

Johannes Hylander
National Agency for Higher
Education, CRUE
Box 7851 103 99 Stockholm
Sweden
Johannes.Hylander@hsv.se

David Wonnacott
CTI Centre for Physics
University of Surrey
Guildford
Surrey GU2 5XH
United Kingdom
d.wonnacott@surrey.ac.uk

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The Australian edition of CAL-laborate is published by:

UniServe Science
Carslaw Building (F07)
The University of Sydney
NSW 2006 Australia

Using SToMP for Teaching in a Small Group

Richard A Bacon

CTI Centre for Physics
University of Surrey
Guildford
Surrey
GU2 5XH
United Kingdom

r.bacon@surrey.ac.uk

<http://www.ph.surrey.ac.uk/cti/>

The SToMP project has been funded largely by the Higher Education Funding Councils of England, Wales and Scotland, and by the Department of Education for Northern Ireland. Substantial contributions have also been made by Queensland University of Technology, Australia and the University of Guelph, Ontario, Canada.

Introduction

The SToMP project (Software Teaching of Modular Physics) has created computer based teaching and learning materials for topics in physics, with a pedagogic style that is based upon distance learning principles. The material has been produced by a collaboration between staff from several different universities, and includes many interactive models, scripts, pictures, diagrams, a glossary, biographies, text book sections, problems, self and assessed tests as well as a set of software tools for data analysis and display.

This case study concerns the use of SToMP materials as part of the formal delivery of a first year acoustics specialist course during the 1997/8 session in the Physics Department at the University of Surrey, UK. This was the third year in which SToMP had been used in this way, but it was the first time that the assessed tests had been used to provide any part of the formal assessment of the course.

The class, and logistics

The University of Surrey Physics Department's Degree in Physics with Modern Acoustics, has two specialist lecture courses during the first year, one being called "Introduction to Acoustics". This includes topics such as quality factor of a resonant system, the wave equation, energy and power of a wave and musical instruments, etc. that are covered in some detail within SToMP, as well as other topics that were not.

The course comprises 40 hours of contact time. Half of this is spent in lectures and half in the computing laboratory. This specialist course has had up to 15 students in some years, but in 1997 had only eight.

Study practices

The PC laboratory used is one of two 20-seat computing laboratories provided in the Physics Department (the other has X-Terminals). The sessions were of one hour duration, spread over 20 weeks. Students worked one to a computer, but the computers are arranged in pairs and there was plenty of communication between adjacent students.

The first session started with a 10 minute introduction as to how the SToMP system worked, what features it offered, and how these features could be used. The first unit within each SToMP module is designed as an introduction to using the package, and students were strongly advised to start by working through this unit. In practice, all the students were more or less *Windows* proficient before starting to use SToMP, and no serious difficulties were encountered.

The recommended SToMP practice when it is used within an academic institution is that academic demonstrators (staff or postgraduates) are present during timetabled sessions to help with academic problems. In the case of this small class, I was present during all sessions and found the opportunity of talking individually with the students very helpful both in getting to know them better and in improving my understanding of their individual difficulties with the topics.

Experiences

As usual when a self-learning tool is provided for students in place of some lectures, there is a strong negative reaction from some students, based upon the idea that

teaching is something that we (the academics) do to them (the students). When the advantages of using such a system (such as the flexibility of learning speed and the close integration of interactive examples with the theory) became clearer, the antagonistic reaction shown by some almost completely disappeared.

Some students also found difficulty at a technological level (e.g. with the size of the text on a monitor, or with sound not being available) without realising that such things were simple to adjust or correct.

For most students, two hours use of the system was sufficient for them to become familiar with the main features. More advanced features were introduced by encouraging the students to revisit the introductory units in weeks three or four.

Student assessment

The SToMP system has the facility for self tests and an assessed test to be provided within each unit, although in practice not all units are equipped with them yet.

The assessed testing system uses a secure database on a local server to record student responses to test questions. The questions are presented within conventional SToMP documents (Figure 1), so that all the SToMP resources are available (e.g. keyword or normal word searches, data books, etc.). Thus, they are equivalent to coursework assignments. A separate answer window (Figure 2) is provided to accept responses to the questions. Feedback messages are provided with self tests but not with assessed tests. This is largely because, for security reasons, the answers are not available on the students' machines.

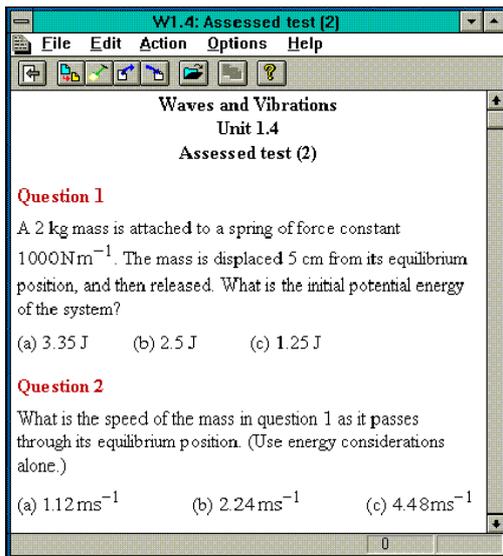


Figure 1. Assessed test sheet (Six question styles are available in SToMP. Only one, 'single selection from a list', is shown here.)

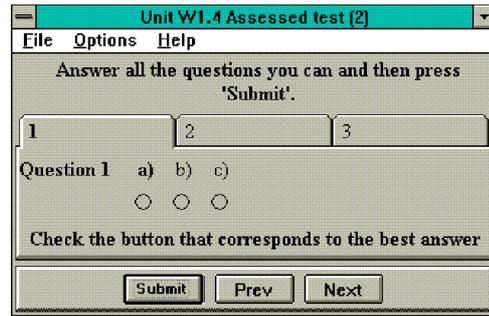


Figure 2. Assessed test answer box

For each unit being assessed, the students were given the date by which the test had to be completed. For each test, the database was primed to allow that test to be taken by the students on this course, and then their responses were marked by the system on the finishing date specified. The marking program (Figure 3) can show the mark for each question, the actual response made by the student, the total percent mark (as shown) or the actual mark. The duration can optionally be shown as well as the time of starting the test. The marks can be copied and pasted into a spreadsheet so that the statistics of the class can be maintained in whatever form is required.

Student Name	Assessment Taken	1	10	2	10	3	10	Percentage
tallon mr peter	May 2, 1998 8:31:11 pm	10	E	10	B	0	D	66.7%
tapper miss nancy	May 1, 1998 4:04:24 pm	10	E	10	B	10	B	100.0%
thackery miss julia	May 7, 1998 12:24:02 pm	10	E	10	B	0	C	66.7%
thorn mr anthony	May 6, 1998 4:41:27 pm	10	E	10	B	0	C	66.7%
tonkin miss alice	May 2, 1998 8:58:06 pm	10	E	10	B	10	B	100.0%
traveller mr scott	May 8, 1998 4:35:32 pm	10	E	10	B	10	B	100.0%

Figure 3. Automatic marking of test questions

Conclusion

The system proved to be very convenient. Some of the units selected were for revision, and with these units it was only necessary for the students to show they were able to answer the questions. With all units tested, the tests themselves provided sufficient motivation for the students to work through all the material (in contrast to previous years where the tests were not used).

I found that the inclusion of the assessed tests made a significant difference from previous years in two ways: firstly the attendance was better, particularly towards the end of the course, and secondly I found that I had a much better idea of how they were progressing. It appeared that the threat of an end-of-course examination was not felt as keenly as a number of end-of-unit tests. The actual results of the tests were not particularly significant, but clearly the doing of them made a difference to the students' appreciation of the course material and thus ensured the whole component was taken more seriously.

Student Multi-Choice Exam Revision Using the Internet

John L Bähr and Bernard T Darnton
 Physics Department
 University of Otago
 Dunedin
 New Zealand

bahr@physics.otago.ac.nz

Abstract

The Physics Department of the University of Otago has for many years, assisted students in their exam revision by supplying past exam papers for 100-level (first year) exams. A list of the correct answers to the multiple-choice section of these exams has also been provided, but these only state *which* of the multiple choices is the correct answer. The students are not shown *why* it is the correct answer, unless they seek help from a staff member. A number of years ago some slide/audio-tape sets were produced, and more recently, exam questions and answers (for 1987-1990) were put onto HyperText Stacks, but the availability (in place and time) was too severely limited to be of use to the majority of students. As first year student numbers now exceed 1000, a more accessible and efficient method of delivering the exam papers to students was required.

We are now using the Internet, to make past exam questions and answers (with working and explanation) widely accessible to students — from anywhere, at anytime, and from any computer platform. With this method we can also gather useful statistical information relatively easily about the process. This paper describes the setting up of such web pages, and how we provide students with help with their physics revision, using the method of multi-choice exams from previous years together with model answers. Statistical information on question access, and results from a student survey are also presented.

Background and history

Why do exam revision?

The learning of physics is enhanced by solving problems, and one good source of problems is past exam papers, especially multiple-choice exam questions. The Physics Department of the University of Otago has for many years, assisted students in their exam revision by supplying copies of past exam papers for 100-level (first year) exams. A list of the correct answers to the multiple-choice section of these exams has always been provided, but these only state which one of the five multiple choices is the correct answer. In order to enhance their learning from past exam questions, and to relieve the pressure on staff answering the same questions over and over again to queues of students at exam time, we have ported the exam questions to the Internet. Thus students can sit at a computer in one of 15 locations on campus, bring up the appropriate web page using a suitable browser, and 'sit' the multiple-choice section of a past exam paper by clicking on the hypertext-links. This use of the Internet makes past exam questions and answers widely accessible to students — anywhere, anytime, and from any computer platform.

First Year paper structure at Otago

The number and type of physics papers offered to first year students at the University of Otago has changed many times in the last twenty years. The present structure (see Table 1) divides students into 'physical science majors' and 'health science majors', and consists of two papers (PHSI 131 and 132) in each semester for the physical science students and two full year papers (PHSI 110 and PHSI 120) for the health science students. (The latter have lectures at half the rate of the former).

Table 1.

<i>Semester 1</i>	<i>Semester 2</i>
Physical Law & its Applications (PHSI 131)	Fundamentals of Modern Physics (PHSI 132)
Introduction to Physics (PHSI 110)	Introduction to Physics (PHSI 110)
Physical Universe (PHSI 120)	Physical Universe (PHSI 120)

The physical science papers assume an understanding of Bursary (final year of high school) physics and mathematics. The health science papers do not assume an understanding of high school physics, and so the basic mathematics required (non-calculus mathematics) is incorporated in the paper.

The exam for each paper consists of two sections:

- 30 multiple choice questions; and
- 4 written-answer questions from a choice of 8.

Each section is worth 50%.

The use of HyperText Markup Language

The 'de facto' standard for documents on the Internet is HTML. A standard 'web page' is written in this language, which is relatively easy to use, and there are many web page editors available for this. The creation of physics web pages must meet a number of criteria, including the ability to produce superscript/subscript, Greek letters, equations, and diagrams.

We have also used JavaScript (McComb 1996) for handling the time, score, opening new windows, and enabling the filling of more than one frame at a time.

Description of the project

General form of the pages

Figure 1 shows the opening page for the exams. From here the students select, via the two 'pull-down' menus, the paper and year of exam (1992-1998). They are also reminded of the changes in paper numbers which have occurred during the last six years.

The general format of the exam pages uses three frames (Figure 2), divided as follows:

- top frame containing header information;
- bottom frame containing elapsed time and exam score — for student's information only — and three links to
 - the exam index page
 - a page of physical constants (see Figure 3)
 - a page of useful formulae (see Figure 4) (these latter two are always included in the 'real' exam paper); and
- centre frame containing the exam paper itself.

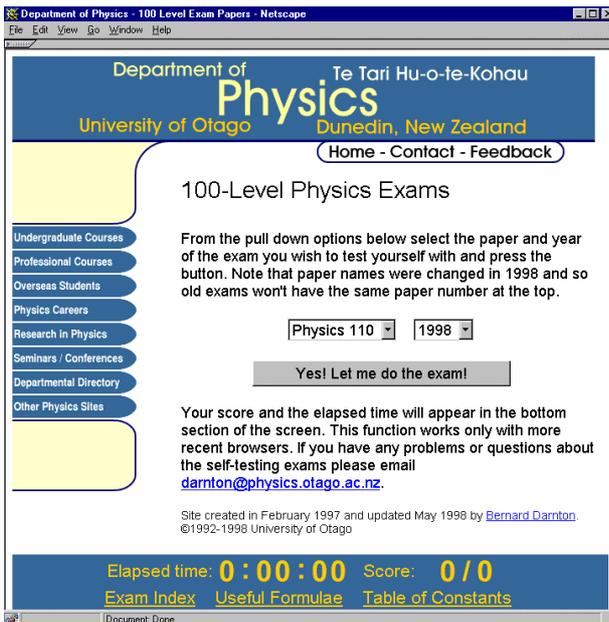


Figure 1. The opening page

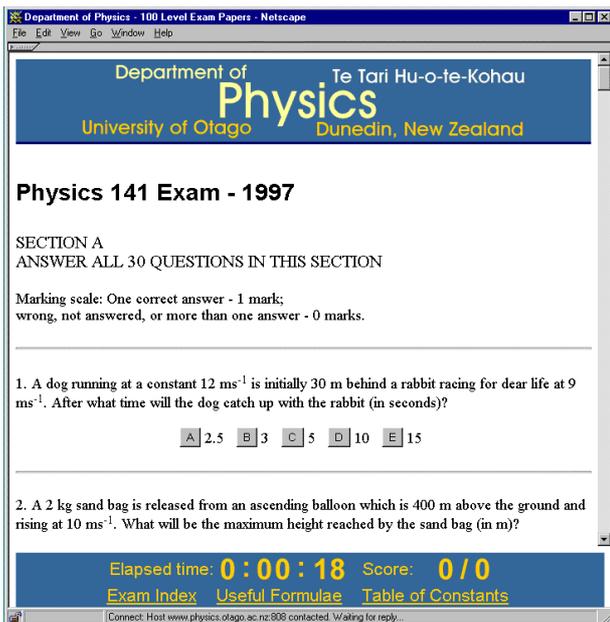


Figure 2. A 1997 exam paper

Students can quickly reference the Constants or Formulae pages, which are normally at the front of an exam paper, by using the bottom frame links which are always present on the screen. We use extra windows for the constants, formulae and the correct answer, so that the variables (time and score) are not destroyed. Figure 2 shows the screen of the page for the 1997 Introduction to Physics paper (under a different paper number, as they were changed from 1998).

Note the use of 'buttons' for the multiple-choice selection, rather than the letters (rendered as hyperlinks) A, B, C, D, and E. The reason is that if the latter are used as HyperText links, the colour changes when clicked, and if the wrong answer is selected, all four wrong answers have the colour changed — an immediate hint to the student that the one remaining unchanged letter is the correct answer!

Table of Physical Constants	
Acceleration due to gravity	$g: 10 \text{ ms}^{-2}$
Permittivity of free space	$\epsilon_0: 8.85 \times 10^{-12} \text{ Fm}^{-1}$
	$k_e = (4\pi\epsilon_0)^{-1}$ $k_e: 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$
Electronic charge	$e: 1.6 \times 10^{-19} \text{ C}$
Electronic mass	$m: 9.1 \times 10^{-31} \text{ kg}$
Speed of light in vacuum	$c: 3.0 \times 10^8 \text{ ms}^{-1}$
Gravitational constant	$G: 6.7 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2}$
Mass of Earth	$M_E: 6.0 \times 10^{24} \text{ kg}$
Mean radius of Earth	$R_E: 6.4 \times 10^6 \text{ m}$
Avogadro's number	$N_A: 6.022 \times 10^{23} \text{ mol}^{-1}$
Stefan-Boltzmann constant	$\sigma: 5.7 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$
Universal gas constant	$R: 8.3 \text{ Jmol}^{-1}\text{K}^{-1}$
Planck constant	$h: 6.6 \times 10^{-34} \text{ Js}$

Figure 3. Table of Constants

Useful formulae for PHSI141 exam		
$F = ma$	$v_{av} = \frac{1}{2}(v_i + v_f)$	$d = v_{av}t$
$d = \frac{1}{2}at^2$	$\Delta v = at$	$a = v^2/r$
$T = 1/f$	$T = 2\pi\sqrt{(m/k)} = 2\pi\sqrt{(l/g)}$	$f_c = f_2 - f_1$
$I = P/A$	$Ir^2 = \text{const.}$	$x = A \sin \omega t$
$y = A \sin [2\pi(t/T - x/\lambda)]$	$W = Fd \cos \theta$	$PE = mgh$
$KE = \frac{1}{2}mv^2$	$W = \Delta(PE) + \Delta(KE)$	$P = W/t = Fv$
$W_{out}/W_{in} = (F_{out}/F_{in}) / (d_{out}/d_{in})$	$v^2 = 2gH$	$p = mv$
$F\Delta t = m\Delta v$	$F = -k\Delta x$	$P = F/A$
$\rho = m/V$	$PV = \text{const.}; PV/T = nR$	$P + \rho gh + \frac{1}{2}\rho v^2 = \text{const.}$
$P = \rho gh$	$F = kq_1q_2/r^2$	$E = F/q$
$F = kq/r^2$	$V = kQ/r$	$V = U/q$
$\Delta V = El$	$C = Q/V$	$U = \frac{1}{2}QV = \frac{1}{2}CV^2$
$I = \Delta Q/\Delta t$	$P = VI = I^2R = V^2/R$	$V = IR$
$R_s = R_1 + R_2 + R_3 + \dots$	$1/R_p = 1/R_1 + 1/R_2 + 1/R_3 + \dots$	$\Delta Q = mc\Delta t$
$Q = mL$	$\Delta Q/\Delta t = kA \Delta T/\Delta x$	$\Delta Q/\Delta t = \sigma \epsilon AT^4$
$\text{stress/strain} = Y = (F/A) / (\Delta L/L)$	$L = L_0(1 + \alpha\Delta T)$	$n = c/v$
$c = f\lambda$	$n_1 \sin \theta_1 = n_2 \sin \theta_2$	$\sin \theta_c = n_2/n_1$
$1/s + 1/s' = 1/f$	$\Delta\lambda = \lambda/(mN)$	$I = (I_0/2)\cos^2\alpha$
$m\lambda = b \sin \theta$	$\phi = 1.22 \lambda/D$	$\phi = \lambda a$
$n = \sin[(A + D)/2]/\sin(A/2)$	$E = hf$	$\Delta N/\Delta t = (\text{const})N$
$N = N_0 \exp[(-0.693/t_{1/2}) t]$	$L_1 = 10 \log_{10}(U/U_0)$	

Figure 4. Formulae given at the front of the exam paper

Using the exam pages

The student can select an exam to 'sit' from the Exam Index page. As soon as the selected exam page loads the 'clock' at the bottom of the screen starts incrementing, which allows the students to time themselves — as if they were sitting a 'real' exam. The student answers each question by clicking on the appropriate button (A to E). If they select a wrong answer a window comes up which

simply tells them that — see Figure 5. When they select the correct answer another window opens to tell them that, and also to show how the correct answer is obtained (see Figure 6).

A score is kept in the bottom frame. The Formulae and Constants windows can be opened at any time, and kept open on the student's computer for easy reference.

Incorrect

Please try again

Figure 5. Incorrect answer window

PHSI 141 - 1997, Question 1, Correct

The difference in speed between the two animals is 3 ms^{-1} . The 30 m gap will be closed in

$t = d / v = 30 \text{ m} / 3 \text{ ms}^{-1} = 10 \text{ s}$

Figure 6. Correct answer window

Examples of questions that make specific use of computer screen capabilities

Use of diagrams in both question and answer

Questions that include diagrams are particularly useful for teaching purposes, since the diagram (or at least the correct diagram) can be reused in the correct answer tutorial. An example of diagrams in the question is provided in the following electrostatics example (first frame is the question, second is the correct answer):

Which one of the diagrams below best represents the form of the electric field lines of a pair of positive charges of equal magnitude, placed a small distance apart on the horizontal axis?

(A)

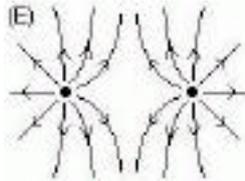
(B)

(C)

(D)

(E)

PHSI 141 - 1994, Question 14, Correct



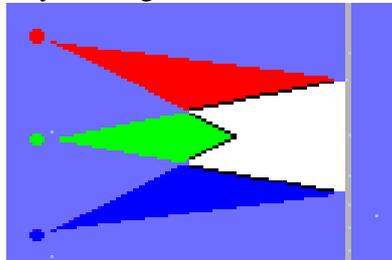
Field lines always begin on a positive charge and end on a negative charge and spread from each other.

Use of colour

One of the important differences between the normal exam format and the computer generated one is the use of colour. This is demonstrated in the following example on colour mixing.

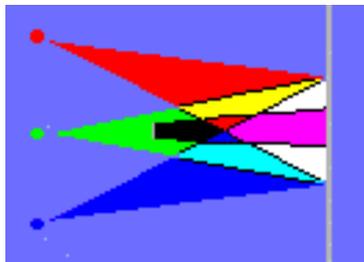
Note — the ability to use colour is a bonus — something that we can't do in an ordinary exam paper, but in the example below we do have to be careful not to give away the answer. For this reason, in the 'question' figure, the proper colours are deliberately not shown in parts of the white area.

Beams of red, green and blue light of equal strength are directed at a white screen, in a darkened room. When an opaque object is placed solely in the green beam the colour of its shadow on the screen is:



(A) red (B) yellow (C) magenta (D) cyan (E) black

PHSI 141 - 1995, Question 7, Correct



The three colours mix to give white, but with green omitted only the red and blue are left to mix, giving magenta.

Pitfalls to be avoided — and some tips

Avoid designing diagrams on a 1024x768 screen and expect them to look good on a 640x480 screen. Trapping code should be used for the Netscape version number, as the time/score doesn't work on Netscape v2. Maths symbols can be unreliable, and this depends on the browser used. For example, the symbol 'sqrt' may need to be used instead of a $\sqrt{\quad}$. The Macintosh version of Netscape v2 has a bug that necessitates a window-opening instruction being repeated. In general, one should design for the intended environment. Our main environment (Macintoshes running Netscape browser) is quite controlled and so we know the fonts needed are installed, and the JavaScript works with every machine it will meet in the environment.

Student assessment and server statistics

Student assessment

At the end of the PHSI 141 lectures in June 1997, students were asked to assess the exam web pages via an eight-question survey form; 320 students (from a class of 525) completed the survey. The results are summarized in Figure 7.

The positive response to Q2 shows that we had done adequate 'advertising' of the exams, but we were rather disappointed by the overwhelming 90% who preferred a hardcopy form of the exam, and the 63% who had not actually used them. We believe that the Q4 result came about because of the difficulties in gaining access to the

CAL laboratories — especially for first year students, and we think that this problem has now been resolved. (Note that the weekly requests just before the mid-term exam in 1997 is approximately 10500 compared to approximately 33000 before the 1998 mid-term exam, where the population has doubled).

The equivalent PHSI 110 lectures don't finish until early October 1998 (because the new paper structure has the equivalent paper to PHSI 141 lasting the full academic year), so we will be running a second survey then.

Server statistics

The software package *Getstats (v1.2)* was used to analyze the server log for all accesses to the physics exams for the period March 1997 to August 1998 (526 days). Figure 8

shows the accesses to all the exam pages on a weekly basis over that time.

The obvious peaks occur in this distribution just before exams (the real ones!), on 28 April 1997 (mid-term), 11 June 1997 (final), 25 June 1998 (final) and 27 July 1998 (mid-term). It is encouraging to see an increase in the use of the exams over the 18-month period.

The final figure (Figure 9) shows the distribution of paper requests by the year of the paper. As might be expected it is the most recent years which are requested most. We also have the capability of analysing the web statistics in detail — in fact at the individual question level — and this will be part of the thrust of future work.

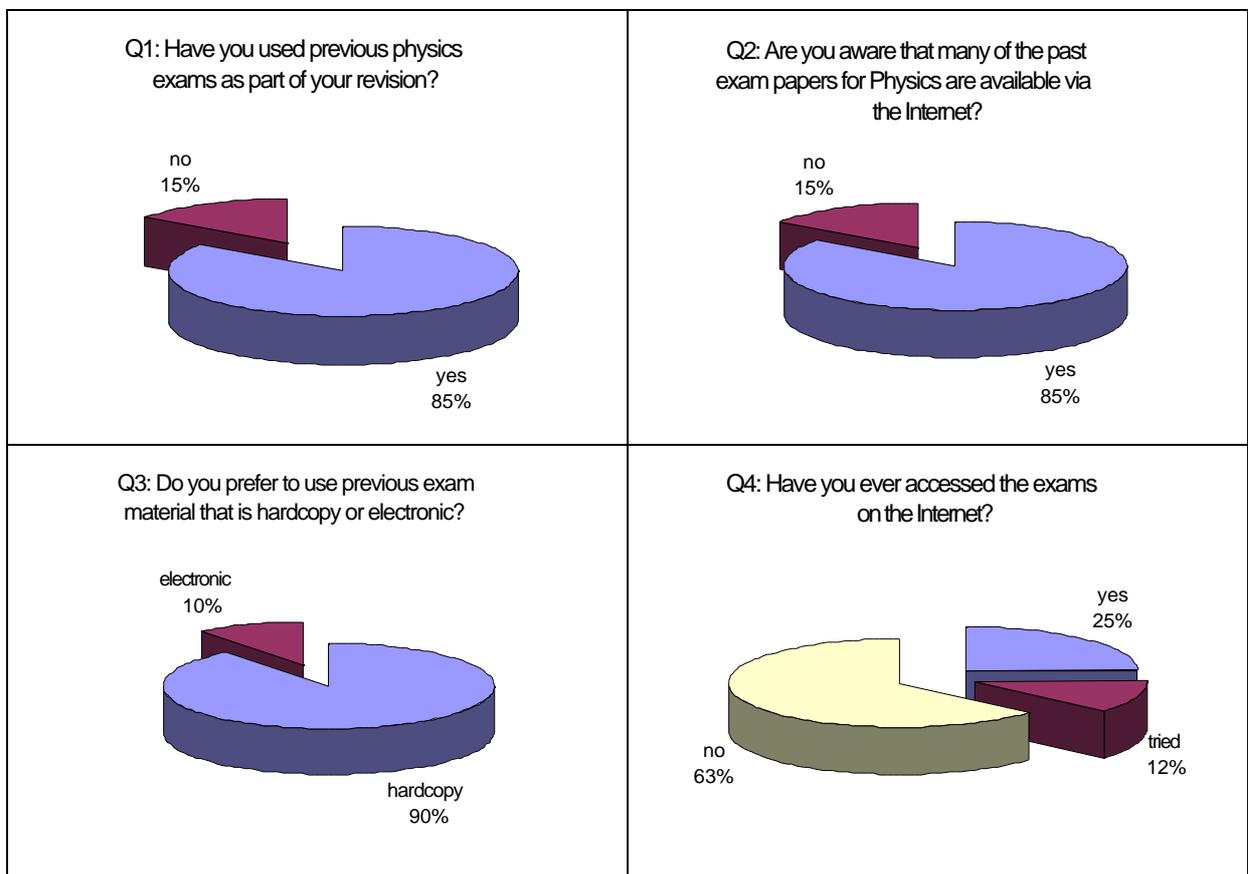


Figure 7. Some results from a student survey, June 1997

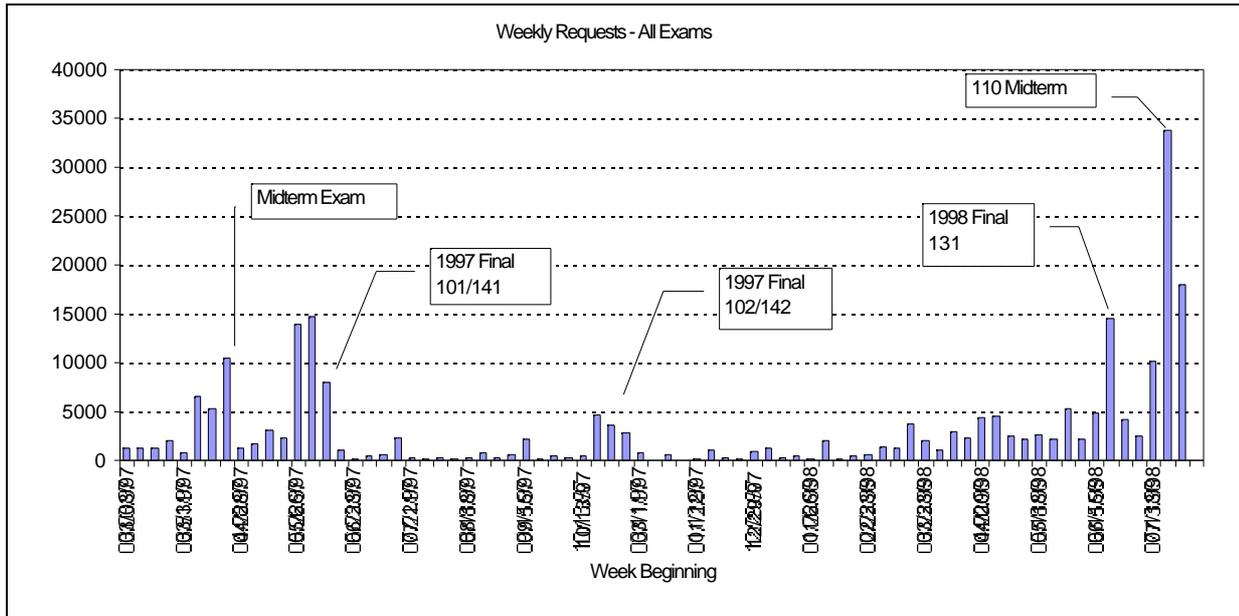


Figure 8. Weekly web requests for all exam papers: March 1997 to August 1998

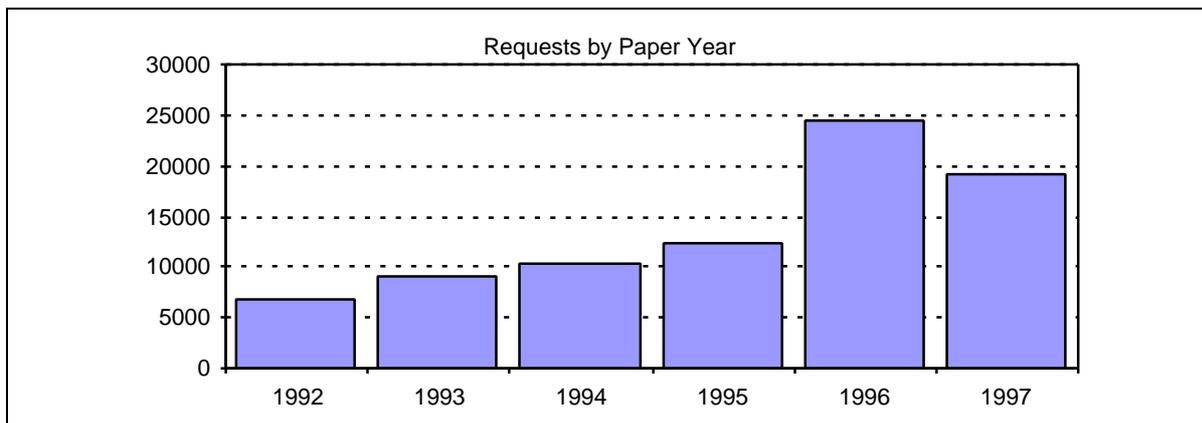


Figure 9. Requests for all exams as a function of year

Conclusions

This paper has described a new way of providing students with help with their physics learning, using the method of multi-choice exams from previous years, with model answers. The students have a chance at trying the problems themselves, and if they cannot see how the correct answer is obtained they have the advantage (over the hardcopy form of the exam paper) of accessing help in the form of model answers to the problems. By using the Internet as the medium, the exams and answers are available from anywhere at anytime.

The use of JavaScript language means that useful additions to the exam papers, such as a table of physical constants and formulae, can be visible simultaneously, as they would be in a genuine exam paper. Other possibilities in using this medium are the use of colour and animation. The former has been demonstrated in this paper, and while we

experimented with some small animations, so far none have been put in place. This may be one of the aims of future work, although this will probably mean departing somewhat from the original 'exam paper' format. In addition, the advantages of animations have to be weighed against the cost in terms of increased creation time and increased download time.

The exams have been available to students for eighteen months, and more students are using the system as they become confident in using the CAL facilities on campus. The students will be surveyed again near the end of 1998.

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Managing Mathematics with *CALMAT*

This article was first published in the CTI Mathematics quarterly newsletter Maths&Stats Volume 9, Number 3, August 1998.

Dexter J Booth

School of Computing and
Mathematics
University of Huddersfield
Huddersfield
West Yorkshire
HD1 3DH
United Kingdom

d.j.booth@hud.ac.uk

The art of good teaching is the art of being organised; lectures ready, clearly delivered with tutorial and homework support. Homework is given out, handed in, marked and handed back on a weekly basis — at regular times and over regular intervals. Learning is work and the student has to develop the habit of regular application if he or she is to succeed. Knowledge acquisition is not an osmotic process; it requires steady graft and continual reflection. If it were otherwise it would not be worthwhile.

But if the student does not participate, no amount of organisation on behalf of the teacher is going to be of worth. The corner stone of a student's participation rests on their willingness to work alone; a willingness that can be stimulated by regular homework followed by regular feedback. Take that away and pretty soon the wall will be breached — the odd lecture is missed — no sanction. Then the odd tutorial — still no sanction. Then large scale absenteeism And then the sanction — failure — but too late. Admittedly not all students follow this pattern but too many do and here is the point at issue; with a large group of first year students how can the habit of regular effort be instilled? How can the teacher ensure that no-one is 'slipping the net'? Clearly weekly homeworks are out of the question with 100+ students and this is where automated systems come into their own.

This paper describes the operation and consequences of a pilot study to use a computer to deliver tutorial activities and continual assessments to a large group of first year undergraduate engineering students¹.

The software

The software is called *CALMAT* and is accompanied by a sister suite called *TASMAT*. It was developed by and is available from Dr Jean Cook in the Department of Mathematics at Glasgow Caledonian University.

CALMAT is a software suite that contains expository material, tutorial activities, some measure of assessment and a comprehensive management information system that ensures that the teacher can maintain course control with a close awareness of student effort. The expository material ranges from GCSE mathematics through to A-level mathematics (Scottish University Year 1) and covers all the topics that one would expect to be familiar to a competent junior mathematician.

The *CALMAT* package opens with a module map as indicated in Figure 1.

The name of the game is to complete modules one at a time in the order prescribed by the teacher. On the introductory module map, each module is indicated by a number enclosed within a grey circle — the lines indicate the sources of prerequisite knowledge for any given module. Canny thought has ensured this map is personal to the student; as the student progresses through the system the circles change colour. Pink indicates that the module has been started and green indicates that it has been completed. It may sound trite but to some students this does act as a spur and none does it deter. Each module is subdivided into small subsections as indicated in Figure 2.

Supplier contact details

The *CALMAT* Team
Department of Mathematics
Glasgow Caledonian University
Cowcaddens Road
Glasgow G4 0BA
United Kingdom

j.cook@gcal.ac.uk
<http://www.maths.gcal.ac.uk/calmat/>

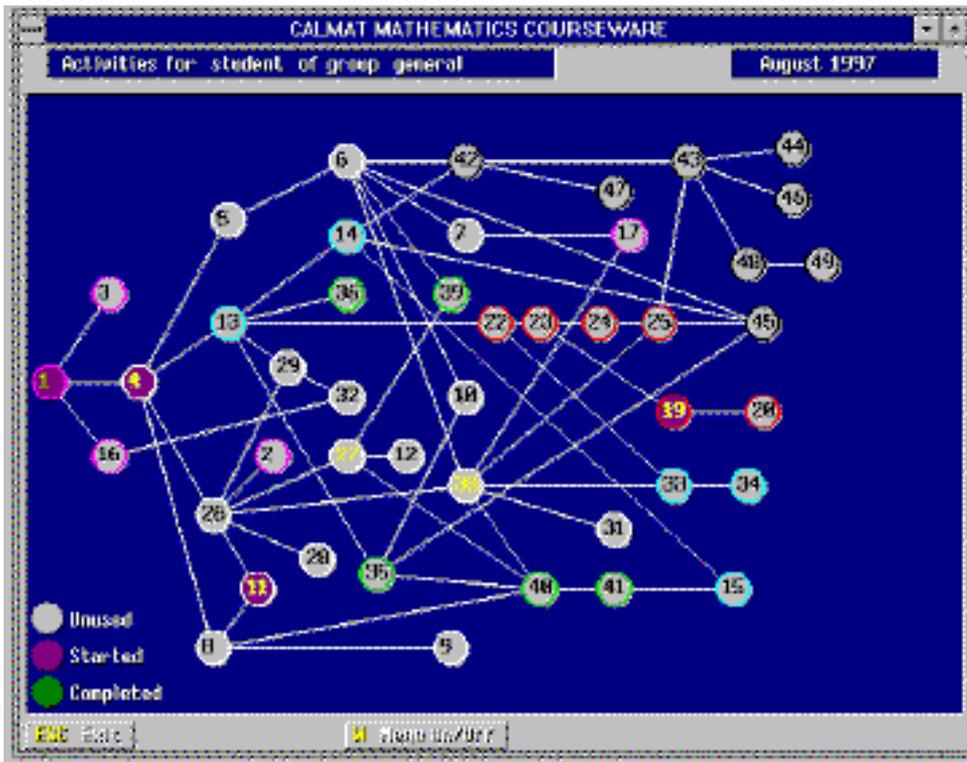


Figure 1. Module map

SEQUENCES & SERIES	
a	Definition and Examples
b	Specifying Sequences
c	Test on Sequences
d	Arithmetic Sequences
e	Arithmetic Series
f	Test
g	Geometric Sequences
h	Geometric Series
i	Infinite Geometric Series
j	Test on Geometric Sequences

Figure 2. Typical subsection list

To complete each subsection the student has to answer correctly a number of tutorial type questions in sequence. If the student enters an incorrect answer then the student has to start the sequence again. This greatly concentrates the mind. When a subsection has been completed the subsection label turns green otherwise it turns pink to indicate that it has been started but not completed. Return is possible to any part completed subsection at any future time. When all the subsections have been completed satisfactorily the module marker on the module map turns green and the student is credited with having completed that module. Some modules have specific assessments included and the scores for these are recorded separately.

Coupled to this suite of software is a Management Information System that enables the teacher to keep a close watch on everything that each student does. The system records effort by group, by student and by module (Figure 3).

Figure 3 displays those modules started (S), completed (C) or not done (blank) by each student for a particular tutorial group of students (the names of the students have been blanked out to comply with the Data Protection Act). The performance of any particular student can also be viewed.

Figure 3. Completion for a group

In Figure 4 we can see the work done by one particular student. The numbers down the right-hand side represent the accumulated time that this student has spent on each

module. Notice that Module 16 is still only regarded as started but has had a significant time spent on it. Why is it not complete? We can look further into this.

# Lesson Name	Status	Score	Last Used Date/Time	Usage(sec)
1 The Real Number System	Completed	98	07/18/1997 15:12	2598
2 Ratio, Proportion and Variation	Completed	8	29/10/1997 14:6	2888
3 Probability	Started	0	11/05/1998 18:36	156
4 Introduction to Algebraic Expressions	Completed	0	29/10/1997 14:28	1281
5 Polynomials	Completed	0	29/10/1997 15:16	2868
6 Factorising Polynomials	Completed	0	29/10/1997 15:45	1789
7 Algebraic Fractions	Completed	0	31/10/1997 14:56	2489
8 Exponents	Completed	0	31/10/1997 15:17	1234
9 Radicals	Completed	0	12/11/1997 13:59	2895
10 Further Algebra	Completed	83	05/11/1997 15:19	8518
11 Sequences & Series	Completed	0	12/11/1997 13:28	3678
12 Absolute Value	Started	0	12/11/1997 14:12	185
13 Cartesian Coordinates	Completed	100	05/11/1997 15:28	1471
14 Equations of Straight Lines	Completed	0	05/11/1997 16:13	2657
15 Applications of Straight Line Laws	Started	0	12/11/1997 14:18	615
16 Matrices and Determinants	Started	0	02/12/1997 14:11	2611
17 Complex Numbers	Completed	0	03/12/1997 15:39	1921
18 Perimeter, Area & Volume <i>(Under Dev)</i>	Unused			
19 2 Dimensional Vectors	Started	0	27/01/1998 15:33	130
20 3 Dimensional Vectors	Started	0	27/01/1998 15:35	97

Figure 4. Completion for a student

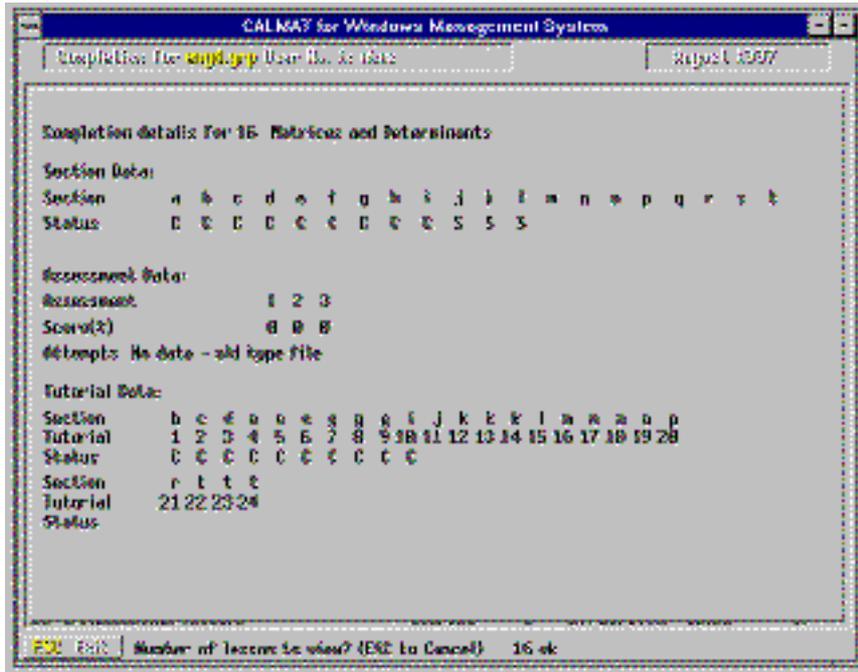


Figure 5. Details of a particular module for a particular student

Here, in Figure 5, we see that this student has a little more effort to expend to complete this module. If it were felt that this student was falling behind or was experiencing some difficulties then it is a simple matter to email the student. I found that widespread use of email was very effective in encouraging and maintaining student participation though there were one or two exceptions to this rule. If a student did not respond to email then it was time to contact the course tutor for further action. Fortunately, this was a rare

occurrence but when encountered was received favourably by the course tutor.

Coupled to CALMAT is a suite called TASMAT which permits assessments to be constructed from a pre-defined bank of questions listed by category. The system is quite simple to use. Firstly, the tutor defines a course — here, in Figure 6, I have defined the course ENG, my engineering students. Figure 7 displays the tutorial groups.

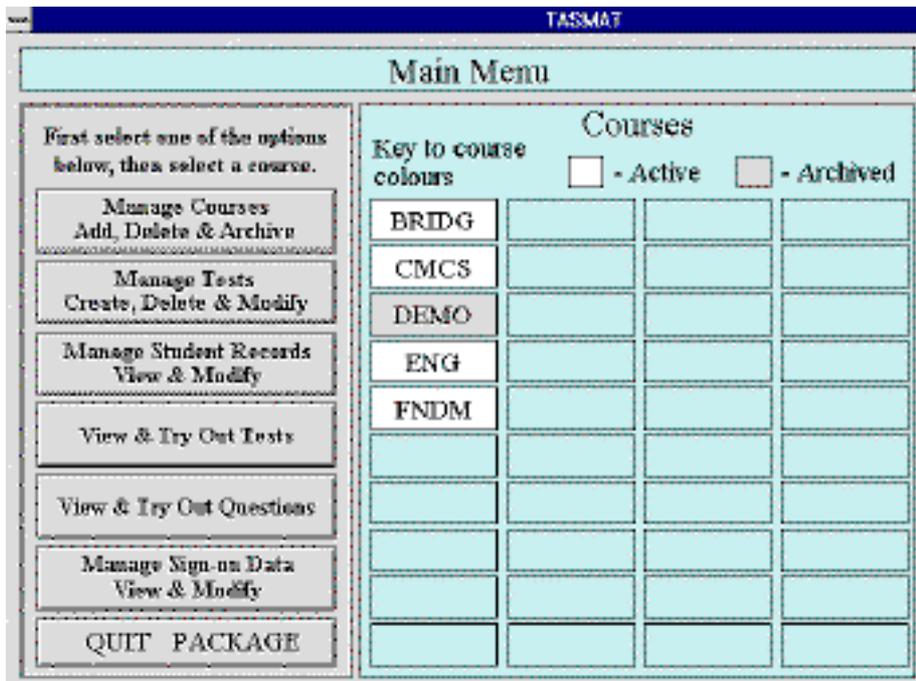


Figure 6. TASMAT screen

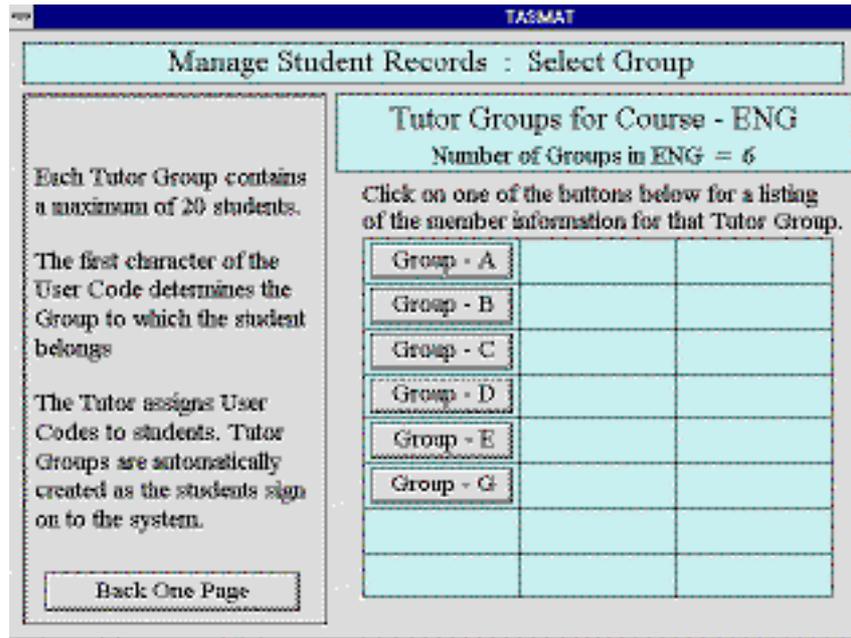


Figure 7. TASMAT tutorial groups

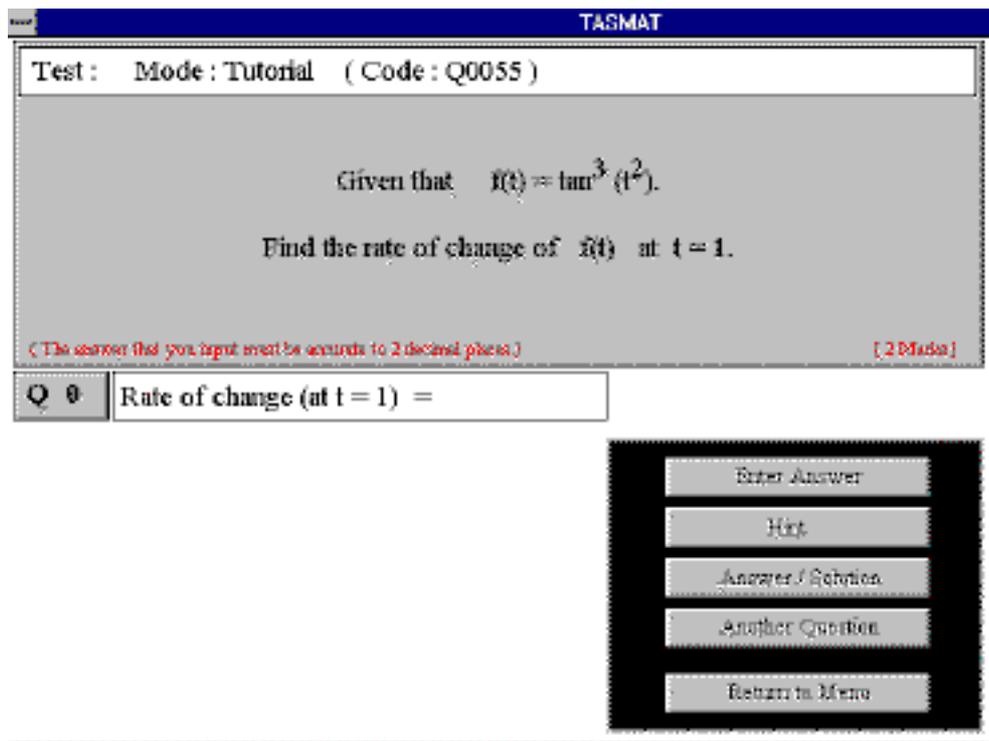


Figure 8. A sample question

Next, a test is created from a bank of questions extant within the system. A typical question is shown in Figure 8. Each test can contain up to ten questions and each question in the test can have up to eight options. Each question contains variable parameters and every time a question is asked the values of these parameters are selected at random. There are two modes for a test. In Tutorial mode the test is formative with Help and Solutions available. By selecting Another Question a similar question can be attempted with a different collection of parameter values. The next question in the test is accessed via the Return to Menu

button. The test can be executed in Tutorial mode as often as wished but the scores are not permanently recorded. In Assessment mode the test is summative with the Help, Solutions and Another Question buttons disabled. The test can only be taken once in this mode after which the score is permanently recorded.

Furthermore, the order in which questions appear is also random when the test is taken in assessment mode. All this functionality ensures that the chances are small that any two adjacent students are going to be answering the same

question at the same time. When the test has been set-up, each member of a tutorial group of the course (up to a maximum of 20) is assigned a unique User Code. A total of 24 groups are possible for each course and when the students log into the system they are automatically assigned to their group within the system. Again, as with CALMAT, a comprehensive management system is available. The student test scores are listed per group — see Figure 9.

The performance of any individual student can be ascertained down to the score for each individual question

as is shown in Figure 10.

The first test has blanks for each question. This is because the system failed to record the marks across the network when it was first put to serious use. Despite the frustrations that this caused it was possible to note each student's mark and then, as tutor, enter the marks onto the record. This raises another important point. As far as is possible test the technology because this is where the system is at its most vulnerable and there is nothing more likely to put a student off than trying to use a system that keeps falling over.

TASMAT													
Manage Student Records : View Test Scores for Group													
Test Scores 11-20		Print	Click students name for detailed records.					Delete Student		Back One Page			
Course : ENG Group : D		Code	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10	Test %
		d02eng	93	100	100	100	100	91	78				95
		d03eng	96	91	90	62	45	55	22				66
		d04eng	85	65	52	33	75	1	1				45
		d05eng	93	96	81	95	85	55	44				78
		d06eng	89	74	86	67	100	64	11				70
		d08eng	93	91	95	100	100	100	44				89
		d09eng	96	91	95	90	85	82	78				88
		d10eng	96	52	90	81	95	64	22				71
		d12eng	81	57	100	76	90	64	11				68
		d15eng	96	67	81	38	85	45	0				59
		d13eng	96	65	100	67	100	64	0				70
		d16eng	85	74	90	71	100	91	44				79
		d17eng	63	48	71	29	75	55	1				49
		d07eng	93	100	100	95	100	100	78				95
		d01eng	93	96	86	81	75	27	22				69
		d18eng	78	39	48	10	50	27	11				38
		d19eng	70	57	71	62	90	36	39				61
		d20eng	41	30	43	43	40	18	56				39
		d21eng	81	83	90	100	90	73	11				75
Group average score per test			85	72	83	68	83	59	30				

Figure 9. Student group scores

TASMAT										
Manage Student Records : Records for Briggs Matthew										
Tests 1-5		Tests 6-10		Print Record	Allow Result	Edit Student Test Records		Back to Group Scores		
Test : 1 Score : 85 %										
Test : 2 Score : 65 %										
q0207	q0127	q0022	q0016	q0188	q0126	q0189	q0130	q0019	q0024	
2/2	0/2	5/5	2/2	0/2	1/2	2/2	0/2	2/2	1/2	
Test : 3 Score : 52 %										
q0130	q0207	q0189	q0127	q0024	q0186	q0132	q0126	q0022		
0/2	2/2	2/2	0/2	0/2	2/2	0/2	0/2	5/5	0/0	
Test : 4 Score : 33 %										
q0092	q0210	q0090	q0212	q0085	q0213	q0091	q0081	q0211	q0095	
0/2	0/2	2/2	2/2	2/2	0/2	0/2	1/2	0/2	0/3	
Test : 5 Score : 75 %										
q0204	q0026	q0147	q0042	q0074	q0048	q0144	q0145	q0041	q0104	
0/2	2/2	2/2	1/2	1/2	2/2	2/2	2/2	2/2	1/2	

Figure 10. Student test scores

The course

The course on which I have been running the pilot installation is a two semester course of service mathematics to 120 first year engineering students from a variety of disciplines. The backgrounds of the arriving students varied widely from A-level, through BTEC to GNVQ with all possible shades of interpretation that such experiences provide. A number of students are 'good' at mathematics, a number are not. Some enjoy the subject whilst others look upon it as a necessary hurdle to cross on their way to a career and may even resent having to study it. The course itself is delivered by two one hour lectures each week followed up by a one hour tutorial. In addition to this the students are expected to spend upwards of three hours per week in 'directed unsupervised activity' (DUA) — a euphemism for homework.

In the past the tutorials have been paper based and very poorly attended. As far as the directed unsupervised activity is concerned, because this could never be monitored it was probably never done. In effect, a significant number of the students were not putting in a consistent effort during the

year and leaving their learning of the course material to a cramming session in preparation for the examinations. With some students this approach pays off to the extent that they do not fail the examination. With an increasing proportion of the students, however, this style of learning has disastrous consequences.

The course structure

The 1997-1998 delivery of the course was re-structured to take account of the software. Each lecture was delineated against one of the *CALMAT* modules and the appropriate course notes duplicated (each module comes with a complete set of course notes). Each tutorial was likewise delineated against one of the *CALMAT* modules and was taken in a computer laboratory. Certain other modules (13 in all) were designated as starred modules and the students were expected to work through these in their own time. This latter formed the directed unsupervised activity. Every three weeks the students sat a *TASMAT* test during their appropriate tutorial. This structure is clearly laid out in the Module Handbook that is issued to the students at the beginning of the academic year as is shown in Figure 11:

Lecture Schedule for Semester 1

Date	Topic of the week	CALMAT Programs	Tutorial Program	DUA Programs
2/10/97	Real numbers and algebraic expressions	1, 4	1	4*
9/10/97	Polynomials and their factorization	5, 6	5	6
<i>Week beginning 13/10/97 - Test 1</i>				
16/10/97	Algebraic functions and exponents	7, 8	6	7*, 8*
23/10/97	Further algebra, sequences & series	10, 11	11	10*
30/10/97	Co-ordinates and the straight line	13, 14	13	14
<i>Week beginning 21/11/97 - Test 2</i>				
6/11/97	Linear equations and inequalities	26, 27	14	26*, 27*
13/11/97	Matrices and linear equations	16, 29	16	29*
20/11/97	Quadratic equations	30, 31	30	31
<i>Week beginning 24/11/97 - Test 3</i>				
27/11/97	Complex numbers and two dimensional vectors	17, 19	31	17*, 19*
4/12/97	Three dimensional vectors and triangles	20, 23	20	23*
11/12/97	Trigonometry	24, 25	24	25
<i>Week beginning 15/12/97 - Test 4</i>				
18/12/97	Introduction to probability	Notes	25	Notes

Figure 11. Course structure

Assessment

The course is assessed by in-course assessment (40%) and final examination (60%). The in-course assessment is built up by collecting points. The seven *TASMAT* tests contribute a maximum of 40 points but, of course, no-one is going to achieve all 40 that way. As a spur to the students to undergo their directed unsupervised activity and so develop their own self-assessment each completed 'starred' module will gain them an extra point. These extra points they can then add to their test points to accumulate to a maximum of 40 points. A number of students took this aspect very seriously to finish the year with a 100% contribution from

their in-course assessment. Needless to say, these very students gained the highest marks in the final examination.

Operation of the course

Apart from one or two minor technical hitches in the early weeks (they did not seem to be minor at the time!) the students have responded to this form of course delivery with remarkable unanimity. The tutorial attendances, instead of dropping down to a trickle as they did in the past, maintained a steady 80% to 90%. The students were enthusiastic in the main and never seemed at a loss for what to do. I arrived at one tutorial at the start of the second

semester, before the first lecture of the semester to find a full tutorial group already beavering away and every student doing something different. As can be seen from the

analysed questionnaire that was issued towards the end of the course student response was very favourable:

CFN105 Mathematics 1 Final Questionnaire Week 9 Semester 2								
	Yes Score	(Percentages)				No Score	Average Score	Score Rating
		5	4	3	2			
Q1 Have you enjoyed the course?	16	26	40	8	2	3.6	71%	
Q2 Do you approve of the use of CALMAT?	21	30	37	11	2	3.8	79%	
Q3 Do you approve of the use of TASMAT?	27	32	24	10	8	3.7	75%	
Q4 Has it helped you organise your studying?	8	32	35	19	6	3.3	68%	
Q5 Has it helped you control your learning?	13	37	35	10	5	3.3	67%	
Q6 Do you feel that you have learned more than if you had paper-based tutorials?	20	20	30	13	15	3.7	74%	
Q7 Do you like the points system for the self-assessed modules?	20	46	16	3	6	3.6	76%	
Q8 Did you find the lectures useful?	10	27	38	17	8	3.4	69%	
Q9 Did you find the handouts useful?	22	33	37	6	0	3.8	75%	
Q10 Do you feel confident about a more traditional course next year?	16	21	38	13	13	3.7	73%	
Q11 Do you perceive your degree course favourably?	7	32	54	5	2	3.5	70%	
Overall satisfaction rating (1 - 5)							3.6	71%
(Standard Deviation)							0.2	
If you like the use of CAL, is it because: (100% did not like)								
1 I can study in my own time	84%							
2 Helps me to organise myself	25%							
3 I know where I am with my learning	47%							
4 Forces a response to questions	46%							
5 It is easier than using a text book	48%							
6 I can see an attainable target	40%							
7 Did you use the learning diary?								
Often	Occasionally	Never						
5%	44%	51%						

Figure 12. Questionnaire analysis

Results

A detailed quantitative analysis of the results of this year's experience would be of little worth as it would be trying to compare two different cohorts of students operating under two different systems; the assessments last year were paper based and fewer in number and the directed unsupervised activity was not monitored. Instead, suffice it to say that the overall success rate was significantly better than hitherto and convinced me that this system was worthwhile. There are just a few caveats:

- It is essential that the tutor maintains a regular watching brief on every student's activity. Email is an invaluable means of maintaining a personal contact with any student who appears to be having difficulties.

- Ensure that the assessments are only taken when the tutor is present — it is possible to lock a particular student out of the assessment mode of any test.
- Give the students plenty of opportunities to practice paper based problems so as to develop their examination techniques. Being tested by the computer is quite different from the traditional form of testing.
- There is a need to consider later effects — will the students demonstrate that they are better prepared for their second year courses than would have been expected from past experiences? I wait to see.

Conclusions

I have been convinced from my experiences of running this pilot study that the only effective way a computer aided learning package can be embedded into a mathematics

course such as this one is to reverse the scenario and embed the mathematics course into a computer culture. In effect, the course becomes a non-human resource centred activity where the teacher becomes a facilitator and the learner becomes freed of temporal constraints to study patterns. Management-speak this may be, but if the student does participate and does succeed then perhaps the process of learning to learn has begun. All that is required of the learner to succeed is the desire to do so and the willingness to react to the immediate feedback on progress that only an automated system can deliver.

*Seated before the computer the learner is challenged to make something happen, to act or pursue, rather than merely react or absorb*².

Furthermore, the course becomes so wrapped up inside the technology that the only way for the student to progress is via the technology which acts as an ever vigilant recorder

of the student's efforts; not only can the teacher maintain a continual record of a particular student's efforts but, and equally importantly, the student can as well. However, and this fact cannot be stressed too much, the enveloping of a course of study within a computer ethos can only be made effective if an over-arching management information system is part of the deal.

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²Rudenstein, Neil L. *The Internet and Education: A Close Fit*

http://www.mcb.co.uk/services/conferen/jan98/vuj/background_paper.htm

Teaching Environmental Chemistry on the Web

Geoffrey T Crisp

Department of Chemistry
University of Adelaide
Adelaide
SA 5005
Australia

gcrisp@chemistry.adelaide.edu.au
<http://www.science.adelaide.edu.au/chemist/academics/gcrisp/home/homepage/gtc2.html>

The Faculty of Science and the Faculty of Agricultural and Natural Resource Sciences at the University of Adelaide have been involved in a joint project on the use of the World Wide Web for the delivery of teaching resources to science and agricultural students. The Faculty of Science has established Adelaide Science Online (ASO) as a multi-faceted approach to the delivery of information to both staff and students within the Faculty, including teaching materials, research opportunities and the minutes and agenda for meetings as well as general administrative data. The facility has a full time manager and uses *Lotus Notes* as the database with a *Domino* server responsible for the storage and delivery of the material. This article will not cover the research and administrative facilities which are considerable in their own right but rather discuss our experience in designing and delivering a new course in Environmental Chemistry with the express intention that it be flexible in terms of the mode of presentation and that it be readily available to students both on and off campus.

Environmental Chemistry II is a second year subject that is taken by a wide variety of students. It is part of the Environmental Science Degree offered by the Faculties of Agricultural and Natural Resource Sciences and Science, as well as being available to Science students in general as one of their second year choices. Non-science students may also undertake the subject so long as they have the required prerequisite, which is a standard full year, first year chemistry subject. Since potential students can come from a number of Faculties and courses, timetabling for the subject was a major issue. In addition, students in the Faculty of Agricultural and Natural Resource Sciences have to divide their time between two campus settings and this can be difficult. Thus it was deemed essential that the course material be available for students to access in their own time.

Planning for the course commenced in a typical manner with the three academic staff who were to teach the subject having a series of preliminary meetings to discuss the aims and objectives, then deciding on broad areas of subject content. The next major discussion point concerned the necessity for a textbook. If the material was to be delivered by the World Wide Web was there a need for a formal textbook? Should the web presentation be encyclopaedic so that a textbook is unnecessary? This discussion was important because the aims and objectives for the course included statements such as: encouraging students to think critically;

enhancing students problem solving ability; helping students gain an appreciation of scientific methodology; and encouraging professionalism. It was decided that a textbook was required as it encouraged students to read a slightly different version of the same material and thus enhanced their ability to coordinate information from a number of sources. Whether a textbook will always be used for this course will be assessed over the next few years as the web site is developed and feedback from students is obtained. Once the course content was finalised we then required a plan for the web site.

Rather than writing the course material and “dumping” it all into web pages, a series of planning discussions were held in which the reasons for using the World Wide Web for teaching *this particular subject* were considered. The initial rationale was ease of access for students who could not physically be on campus. The discussions then proceeded with the importance of linking all the teaching and assessment material so that a student could make sense of the “bigger picture” of the subject, as well as individual pieces of information. Since the Faculty of Science was using *Lotus Notes* as the database for the delivery of some of its courses (ASO), this became the natural vehicle with

which to deliver a new subject such as Environmental Chemistry II.

The first major item that had to be addressed was whether to use an open or closed site for the subject. What is the economic value of the intellectual potential of the teaching material? Should we share our resources with other tertiary institutions or make others pay for access? Who is likely to benefit from open or closed access to the material? The whole question of open access to information on the Internet will continue to be discussed and no doubt a variety of opinions will ensue. It was decided at this initial stage to restrict web access to students enrolled in the subject.

The front page was designed to be as simple as possible without the need for split screens and scrolling (Figure 1). The section headings were also kept to a minimum so that students did not have to remember complicated navigation terms. The term, course notes, was used instead of lectures in order to emphasise the fact that we were moving away from the traditional, passive, didactic lecture style and attempting a more interactive approach with students.

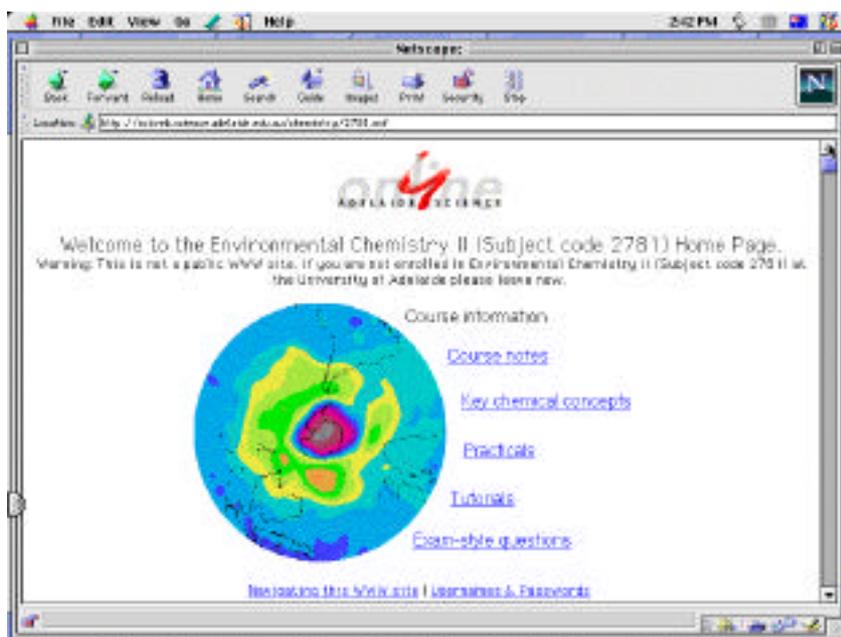


Figure 1.

The database approach to building the web site makes it easy to link the course notes to key concepts, practicals, tutorials and exam-style questions. These were the primary sections which we thought would be of concern to the students. Course information contained the usual housekeeping data as well as the aims, objectives and expectations for the subject. By combining all this material online both the staff and students have an opportunity to observe the relationships between different parts of the subject.

One idea, which we developed at the planning stage for the web site, was the notion that as the site was a database;

selected information could be made available to students in other courses and subjects. Many of the concepts that are taught in chemistry are fundamental to many subjects and are dealt with in a repetitive manner by different teaching staff. We thus identified “key chemical concepts” and decided that for any subject we built in a web format that this heading should appear and that the information should be available for staff and students in different subjects. Concepts such as S_N1 and S_N2 are common to many chemistry subjects and rather than each staff member having to prepare individual course material it is more economical to prepare a single entry which is then made generally available. Within the web pages for these key

chemical concepts the degree of complexity can be built up so that introductory students are not overwhelmed with detail that they do not need and advanced level students can be given a more rigorous treatment of the topic. This is another major advantage for the database approach to building web pages for course material. Students can use these pages for revision in any subject they are studying.

The next issue that was addressed was the number of levels available within the web site. Would students get lost down

some mineshaft of information, never to see the light of day again? We thought that three levels were sufficient and that this would make it easier for students to either navigate in a linear sense or access the data in a format of their own choice (Figure 2). A set of standard navigation buttons was provided at the top and bottom of each page. Since the web site is actually a database rather than a sequence of web pages, the information contained in the database could be manipulated in various ways.

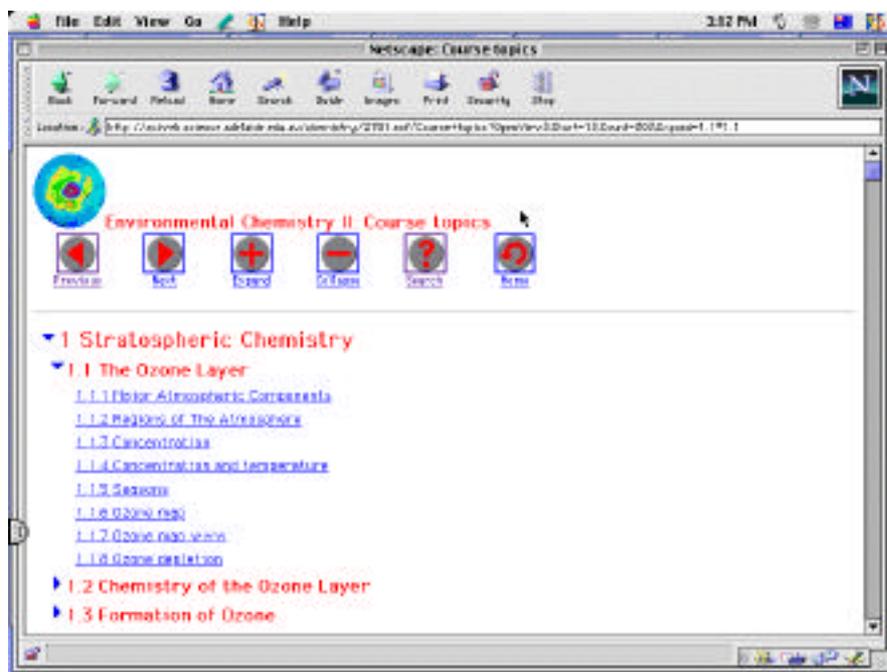


Figure 2.

The course material was assembled using a standard word processing application and chemical structure drawing package and then copied and pasted directly into *Lotus Notes*. Apart from minor formatting adjustments no further manipulation was required to build the web site. The ASO manager prepared the *Lotus Notes* template and page attributes and the teaching staff built the content of the pages. Since previous templates were available for us to review we could make changes to these so that the appearance and navigation aspects of the pages were simplified for students.

Another advantage to the database approach is the ability students have to undertake word searches and so compile their own databases (Figure 3). This effectively amounts to an individual web site with students organising the course material in a way that could be more suited to their individual learning behaviour. This is a concept we have only begun to explore, the idea that students can make sense of course material in alternative ways. Teaching staff may have a specific reason for presenting course material in

a particular order and format but students may also find it advantageous to rearrange this material for their own unique learning path. Having access to an entire subject in a database format enables students to explore this possibility. We did not pursue this aspect this year but will in future years.

An example of a search for the word 'nucleophile' is shown in Figure 4. The concept of a nucleophile is used in many chemistry subjects. The database approach would allow students to take a concept such as a nucleophile and see the broader context in which it is used. This is difficult to achieve in individual lectures where the teaching staff are often concerned with the details of one particular aspect of the subject. Since staff would have access to many of the subjects in the ASO database they could also do keyword searches for important concepts which they are using as part of their teaching and so investigate its importance in cognate areas. This has the potential for a more cooperative teaching approach amongst staff.

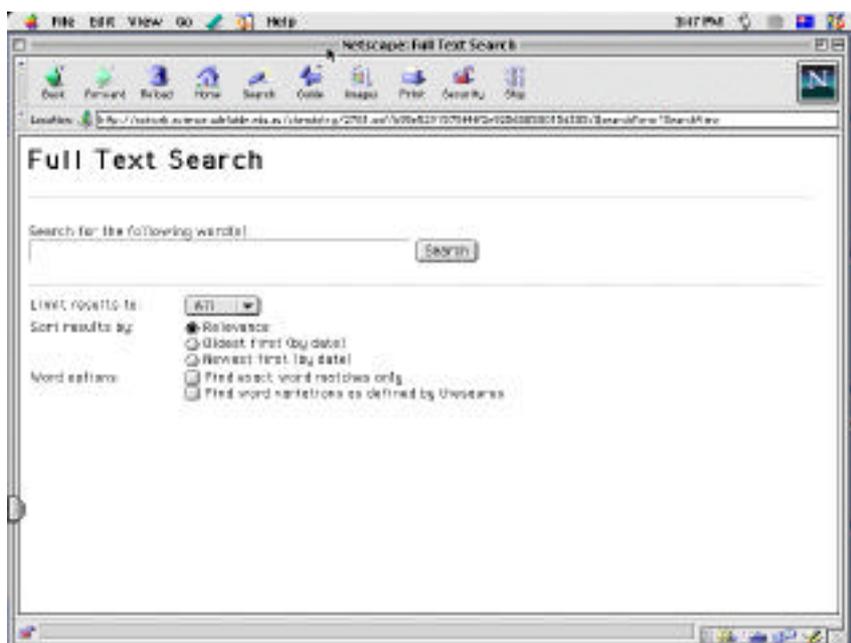


Figure 3.

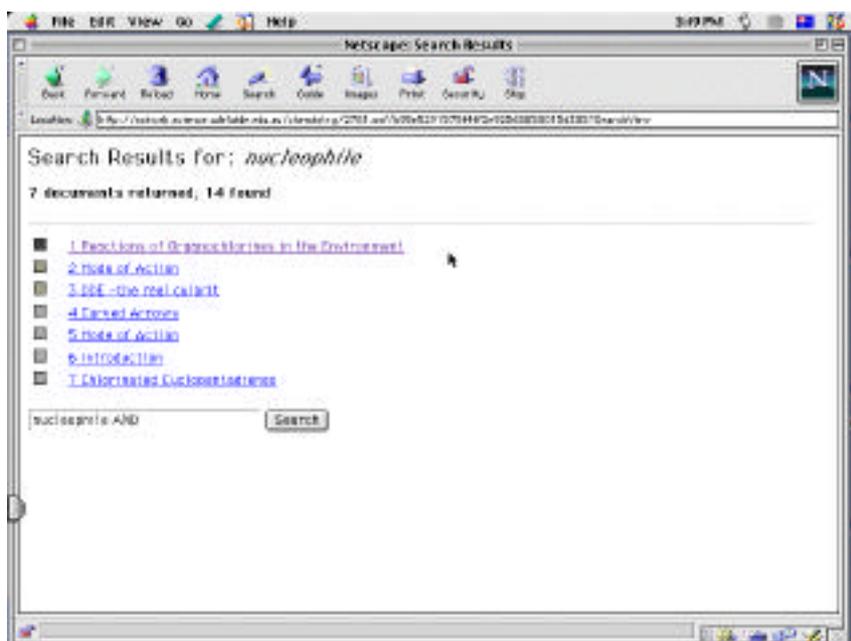


Figure 4.

There is a great deal of information available to students and staff on environmental chemistry on the World Wide Web. We have only just begun to embed URLs into the course content for students. Students can be overwhelmed with too much information and we will have to be careful not to overload them with unnecessary, peripheral material. Staff must always be mindful of the aims and objectives for the course and define clearly for students what is essential material required for the subject and what are additional resources provided for individual investigation. It would be a pity not to provide avenues for students who are motivated to pursue a concept or topic further as part of their own curiosity driven learning.

Although all the course content was available on the web site, traditional lectures and tutorials were still used to present the material. This included traditional overhead projector slides and using the web site directly as an on-line teaching resource. All of the students copied the web pages before the lectures and used these to annotate during the face-to-face lecture sessions. One issue that rapidly became obvious after discussions with the students was the wide variation in prior knowledge amongst students on using web browsers and copying material from the web. We had naively assumed that most students “surfed” the web regularly and so had a basic understanding of web protocol. Simple issues like students copying web pages directly

from the web browser can be quite wasteful because of the headers and footers which accompany each page and the fact that font sizes can be set for visualisation rather than printing. Many students did not realise that the font size could be changed on the browser. This highlighted the need for a training session with students on how to use the web browser efficiently. It is often more convenient to copy the text and diagrams to a word processor and format the content at a later stage than print directly from the original web page. This also highlighted the fact that many students did not realise that graphics in web pages needed to be copied separately from the text. When this subject is presented next year we will set aside time for a training session so that students can make efficient use of their time.

Lecturing directly from the web page was used for one section of the course material. The actual web site was projected onto a screen in the lecture theatre and the material discussed. One of the disadvantages of using the site directly for this particular section was the volume of material on each of the web pages. Even though the material was not read verbatim but concepts highlighted and mainly graphics used, students indicated they felt overwhelmed when seeing too much information on the screen in the lecture situation. This was to be expected. We are now designing the web pages so that a page of information is summarised in a single screen size (much like an overhead projector slide) on the top of each page

and this is presented to the students in the lecture situation. We anticipate that students will then download and copy the main contents of the web page for further reflection and in depth consideration at a later time. This format will also serve as a useful summary of key concepts for both teaching staff and students.

No technical difficulties were encountered in lecturing directly from the web site but as a back up in case the site was not available the material was cached onto the hard drive of the portable computer used for the presentation so that continuity of format could be maintained. Detailed tutorial answers were available from the web site but this did not replace the normal contact time with students for reviewing questions.

Student feedback on this format for course presentation was generally favourable. Some of the concerns expressed by students have been discussed in the above text and we have been able to address them as the course progressed or will introduce the necessary changes next year. The students and teaching staff are in the early stages of realising the potential of web pages in a database format and as we all become more familiar and comfortable with the technology we will all benefit from its use. We are looking forward to presenting this subject again next year and hope to make better use of the facilities and resources we now have at our fingertips.

Examples of Web-based Teaching in Physics

David Green

Department of Applied Physics
University of Technology, Sydney
Broadway
NSW 2007
Australia

dcg@phys.uts.edu.au
<http://www.phys.uts.edu.au/~dcg/>

In this article I describe examples of the use of web technology in my teaching of undergraduate physics subjects. Some of the developments, borne out of the opportunities provided by the World Wide Web, were admittedly led by the technology first and refined during their implementation. A number of the developments I describe have arisen out of identified student needs and are providing assistance in the development of students' understanding of core concepts and skills in Internet technologies.

Introduction

The use of web-based techniques such as asynchronous discussion groups, and interactive web-based multimedia is beginning to fill an important part of on-line learning strategies in university courses. The potential of on-line methods in the teaching of advanced science concepts has been realised^{1,2}, and is most effective when the strategies employed to involve students are well designed for the learner³. In this article I describe a number of developments including a virtual learning centre, an implementation of the "learning dialogues" concept using a newsgroup format, an interactive multimedia package for magnetism and an elegant solution to an emerging problem: writing mathematical notation on the World Wide Web.

Web-based teaching system

A hybrid web-based teaching system⁴ was purpose built from freely available

software running under the *Linux* (an Unix-like operating system for personal computers)⁵. The same server⁶ hosts a number of single subject web sites as well as the Virtual Physics Learning Centre and support for web-based equation editing. The web site for each subject or student group is comprised of four categories of facilities:

- *digital resources* (notes/multimedia/solutions/hints)
- *interaction facilities* (email/virtual tutors/newsgroup/chat)
- *administration functions* (scores/student profiles/assessment tasks and deadlines)
- other *virtual spaces* (links out/web gallery/diagnostic centre)

Registration for the web site required the student had already obtained an email address (free through the University or from a commercial Internet service provider), and to complete an on-line registration form. The design of security and access modes makes each web site the electronic equivalent of a face-to-face class in so far as the interactions and resources are available only to registered members of the electronic classroom. In so doing, opinions and misconceptions expressed by individuals would remain within the group. Access to each subject/group web site is protected by server *htaccess* (username and password) control. The UTS (University of Technology, Sydney) student identification number, though somewhat impersonal, provides a unique 8-character username. Remembering passwords did provide difficulties.

Proprietary systems, such as *WebCT*, *TopClass* and *WCB*, that provide much the same features and functionality, are

now available.

The student profile

As part of the registration for the web site students were asked to complete an on-line survey. The survey was intended to gauge their experience of, and confidence with, web-based technologies, as well as their access to the Internet and any concerns they might have about web-based teaching.

The profile of the students has been an ever-changing one. The data collected represents a snapshot in the first half of 1998 from a sample of N>175 students undertaking a physics subject:

On campus full time (i.e. greater than half load)	84 %
Have remote access to Internet (work or home)	57 %
Are engineering students studying physics	81 %
Fraction of the part-time students <i>with</i> remote access	78 %

Students' perception of their experience with Internet technologies was measured using a 3 point Likert scale. As can be seen in Figure 1, nearly all respondents claimed some experience in the core technologies of WWW, email and search engines. The majority of students however were not so experienced with email listservers and computer mediated discussion. (Care was taken to explain the meaning of these terms in the survey form).

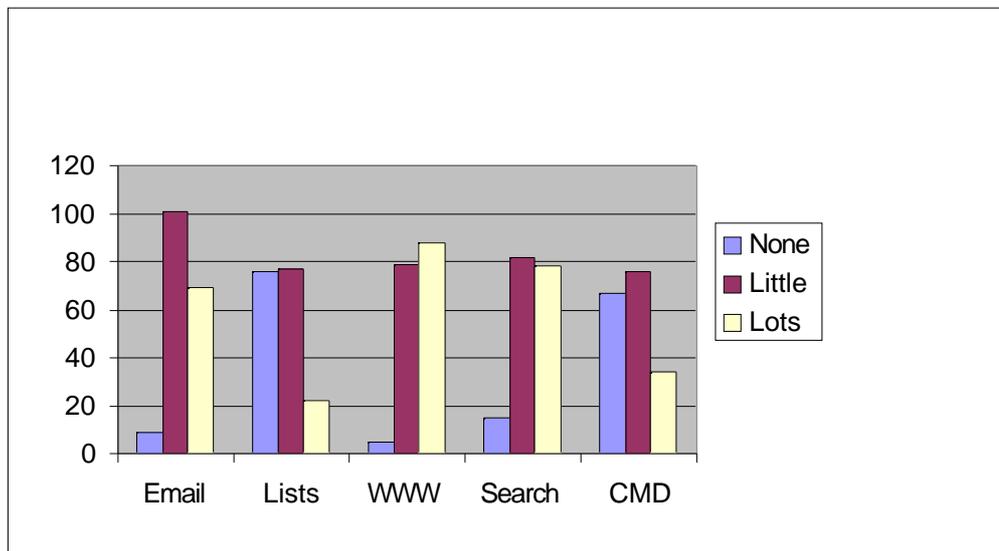


Figure 1.
Students' ratings of their experience with Internet technologies
(Lists=Listservers, Search=Search Engines, CMD=Computer mediated discussion)

Students' confidence with these technologies was also probed. It was possible that experience with the technology may not have ensured a confidence with its use. For instance this comment from an engineering student well into his/her degree and with ample experience of using word processing and spreadsheet packages for work:

I view myself as computer illiterate; hence I have little confidence in utilising the technology.

The student responses however showed that in excess of 50% of respondents claimed to be very confident in the use of the core Internet technologies. Approximately 20%

described themselves as not confident, but few described themselves as being worried about using the web.

Open feedback was also sought about any concerns they had at the outset:

It's going to make the course and/or assignments more difficult than usual.

I've only used the Internet for fun so far, and I'm a bit hesitant about using it for coursework.

I attend Uni. on ... only and I find using the web etc very time consuming.

Call me old fashioned, however I prefer to learn from a human being.

Strategies that will engage students in on-line learning activities must:

- recognise the range of experience and confidence students have;
- assist students who are concerned and/or might be left behind; and
- guarantee access to those who do not have ready access to the Internet.

Virtual Physics Learning Centre (vPLC)

The Applied Physics Department has for many years run a drop-in centre to which students can come to study. For several hours each day a tutor is rostered on to assist with any problems students have. The strategic initiative by the University into flexible learning prompted the development of a Virtual Physics Learning Centre (vPLC) to provide some of these same support functions but in remote mode. This is especially important for students who have difficulty attending at the rostered times.

Involvement in the vPLC is completely voluntary for students and staff. The Virtual Centre was advertised widely at class and on notice boards and as a result, was well supported (approximately 40% of eligible students and 25% of staff). The main emphases of the Virtual Centre are:

- to provide equity across different strands of new first year subjects;
- to provide an avenue for timely updates, corrections and advice;
- to facilitate some self-help with on-line diagnostics and FAQ's; and
- to provide one-to-one help (Virtual Tutoring) and interaction with fellow students.

The vPLC web site has the same generic structure as that described for the web-based teaching system. An important challenge in such a facility is the need to keep the web site looking fresh in order to encourage frequent visits from students (without enormous time input from the manager). One strategy employed was to include a highlight box that could be easily changed weekly (or even daily). The highlight box was produced using a "server include" — a small dynamic element within an otherwise static web page. An example is shown in Figure 2. An analysis of pathways taken by students through the web site showed that many would follow the link in the highlight box, and then dig around for other resources. Overall the first year students were most often downloading hints and solutions to worked problems (which were made available in a trickle through the semester). They were reluctant to get involved in on-line discussion of open questions and rarely used the email list facilities. Staff noticed that they tended to receive individual emails from students in their face-to-face class, instead of the more anonymous "Virtual Tutor" route.

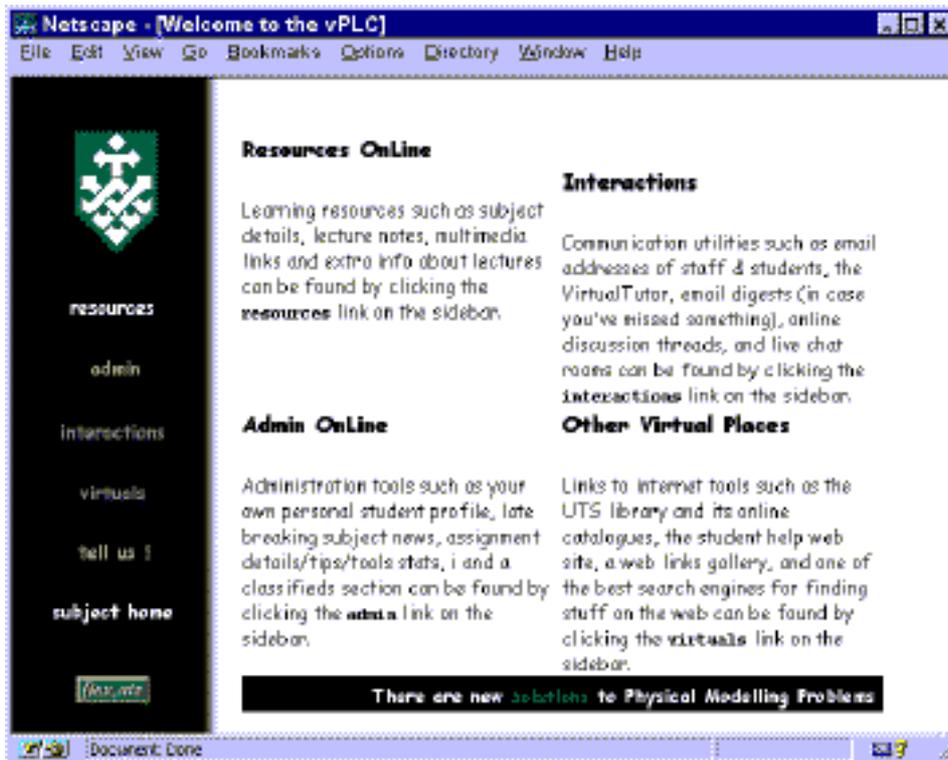


Figure 2. Screen from vPLC showing the message banner at the bottom

Feedback such as the following comments highlight the benefits (perceived by students) of having 24 hour remote access to resources:

Hi it's [me] again, as I pointed out in my mail before I think that the vPLC helped me out heaps and if it wasn't for it I think I would have not got the mark I received. Before the physics exam there was not enough time to go to Uni., find a physics lecturer and try to work out answers with him/her. The vPLC was a perfect solution (for those with access to the Internet of course).

I would like to thank you for the effort you put into

the Virtual PLC — I found that it really helped me out with the physics work I had to do.

Just wanting to thank you for the vPLC as it has been a great help in my study for this final Physical Modelling exam. I've mainly used it for the worked answers and the corrections to the answers. It's been a great help.

On the other hand, the web server statistics shown in Figure 3 paint a somewhat grim picture for student study habits in the lead-up to the final examination. The two tallest vertical bars in the graph correspond to the days prior to each of the first year physics examinations.

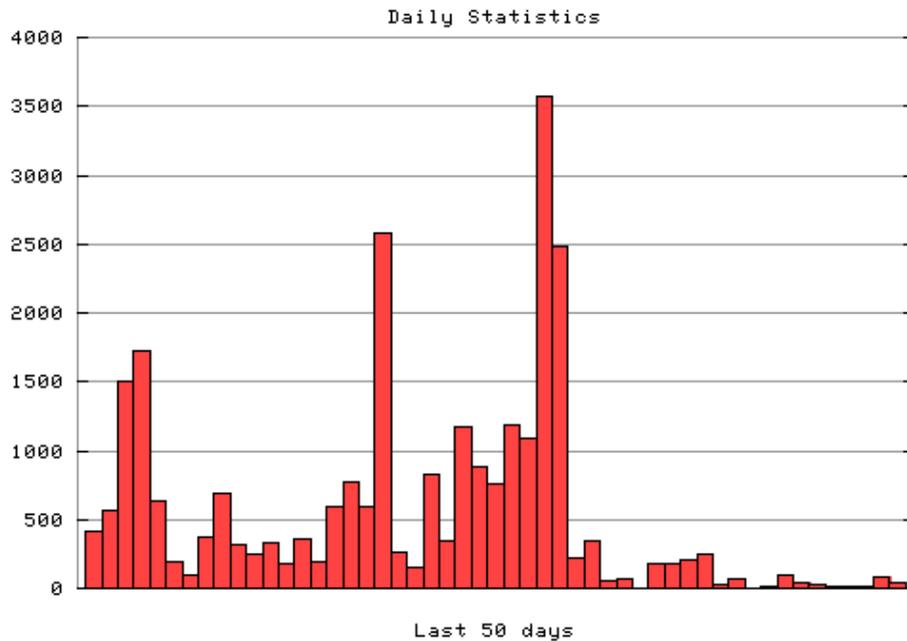


Figure 3. Daily server activity commencing (on the left) with the last week of semester and continuing past the end of the examination period. Each vertical bar represents the number of server “hits” (html documents and images) in each day.

Encouraging learning dialogues with newsgroup software

This work has its origins in the many emails to and from students that were most often of an administrative nature. However amongst this correspondence there were genuine attempts on the part of students to formulate mature questions, and to provide reasoned “self-answers” inviting comment. The benefit of this *semi-formalised* “thinking aloud” has been recognised as an important attribute of computer mediated discussion.⁷

Open feedback was sought from students as they embarked on the learning dialogues project. In particular they were asked about their interest in web based learning:

My interest in Internet based learning would be solely on being a discussion group. We can use this session to discuss the problems encountered during lectures and perhaps come up with answers for them.

The Internet is the future and I find it quite useful and efficient in the amount of time it saves you and you can get some good information from it if you know where to look.

Internet and interactive learning is a “hands on” teaching practice and enables the user to dictate the pace and content of material learnt. My interest lies in the Internet as a teaching tool.

To have the flexibility that Internet based learning offers. The attendance at lectures can be difficult for people who are working and studying part time.

I think that it is a very good idea because Internet access is accessible to everybody, and you can go in and study outside specific lecture times. As well as this, for example, if you had a problem with homework, prac. report or so on, rather than waiting until tomorrow to seek the aid of a lecturer/demonstrator, you can just log on and (hopefully) solve any queries.

Trying to stay with technology and its advantages.

These comments suggest a willingness on the part of students to “give it a go”, and perhaps some subscription to the hype about the future of Internet-based learning. In this section I describe a strategy to utilise asynchronous discussion techniques and to engage students in a significant learning task.

A strategy has been developed to engage students in dialogues with each other, with the teacher, and importantly, internally with themselves. A teaching and assessment strategy has been developed that engages students in “thinking aloud”. The asynchronous discussion format provides a flexible and interactive vehicle for this thinking to take place. A small number of key concepts in the subject are dealt with in this way.

The important elements of the strategy are:

- open questions as the stimulus (room for interpretation in question and answer);
- exploration of the question can usually take place at several levels;
- each question (module) starts a fresh newsgroup;
- questions are set as prework for next class (often revision of earlier studies);
- virtual tuition (comments/arguments) from peers or teacher;

- self review later in semester; and
- participation in the discussions forms a small part of the assessment.

Newsgroup software (*HyperNews*) which supports multiple threading and indentation of responses was used for its simplicity and robustness. The software supports a variety of modes for the attachment of messages including a “smart text” as well as HTML and the embedding of entire URLs.

Figure 4 shows schematically the life cycle of a module down the right hand side with the key teacher inputs on the left. A module will remain “active” for at least four weeks to allow stragglers to complete (commence) the module. The input from the teacher feeds in, where necessary, to ensure discussion proceeds productively. Critical stages have been found to be just after the module stimulus is posted, and at the end, when contributions from students are synthesised into a summary record. To encourage student involvement, the students’ participation in modules is assessed. The weekly activity, amounts to 5% of the subject assessment, and is assessed primarily on participation. To ensure that all students had the opportunity to consider the prework modules prior to class, a computer laboratory is made available immediately prior to class.

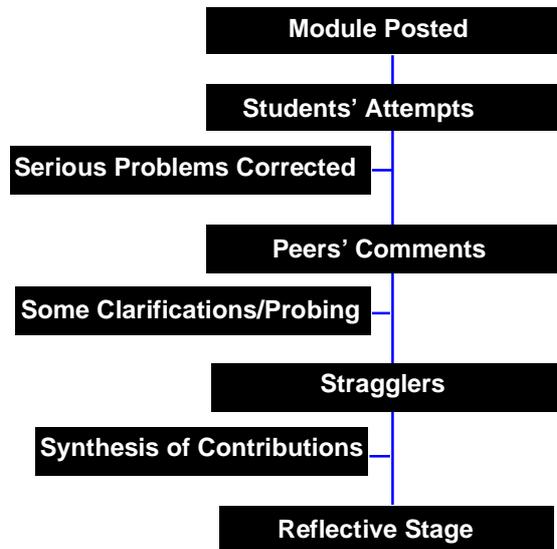


Figure 4. Schematic diagram showing the timeline of a learning dialogues module. The involvement of the teacher at key points in the process is shown as inputs from the left.

Some implementation issues arose. Although the newsgroup format encourages interaction, a good answer, early in the thread of responses, tends to kill discussion. The role of the teacher here is to draw out some broader issues to keep the discussion fuelled, e.g. by seeking clarification from individuals who seem eager to agree with the previous person.

In a prototype system, students were not aware of other students’ responses prior to submitting their own answer. Instead, new responses were incorporated into the newsgroup database using purpose written CGI scripts that returned to the student’s browser, a sample of the previous responses and the invitation to comment. There are a number of pros and cons for the two approaches. For

example from a student's point of view "does it feel like a discussion?" or "does it feel like a test?"

The learning dialogues project has been evaluated at various stages and at two levels, namely technical and in respect of intended learning outcomes. At the technical level, there are questions and issues like:

- from the early days (1995) almost half had some form of remote access (at least a text browser available by dialling up the Unix systems);
- bookings of computer labs for prework required staff supervision to ensure those students got the access;
- on-campus availability was poor at other times; and
- the prework took much longer than staff expected.

At another level, there are the learning outcomes:

- learning dialogue tasks helped with understanding content;
- most found it somewhat difficult to express scientific ideas in words;
- difficulty finding topics prior to the lecture;
- Virtual Tutor was not helpful when being deliberately vague; and
- there was measurably better performance on questions in the final exam relating to the conceptual understanding of the issues raised in the on-line work.

A reflective activity, utilising the on-line discussion software was also developed that involves the communal compilation of the "Hot100 Topics". Contributions from students and staff can take the form of questions/pleas for help/checks on sanity, with replies in the form of peer answers/comments/advice. The evolving archive of students' contributions provides considerable insight into the students' grasp of the subject matter.

Doing mathematical notation on-line

Disciplines such as physics, mathematics and engineering (those in which the use of mathematical symbols and equations are an essential part of communication) are presented with an extra hurdle in the development of web-based teaching materials and strategies. Although there are several ways to produce web compatible mathematical notation they nearly all make the tacit assumption that you will write your bit of mathematics once, put it onto a web server and then leave it alone. These methods include:

- writing them out by hand and digitising the page;
- typesetting the mathematics using a word processor (Save As HTML);
- using a *Mathematica* (V3.0) Notebook and exporting as HTML or LaTeX; and
- using LaTeX and embedding in web pages or converting to HTML.

The use of on-line discussion tools in technical disciplines presents an immediate difficulty. None of the methods outlined above is appropriate to the fully interactive situation such as a hypertext chatroom or asynchronous

discussion. There is a need to interactively compose and use mathematical notation within the web browser, easily and quickly.

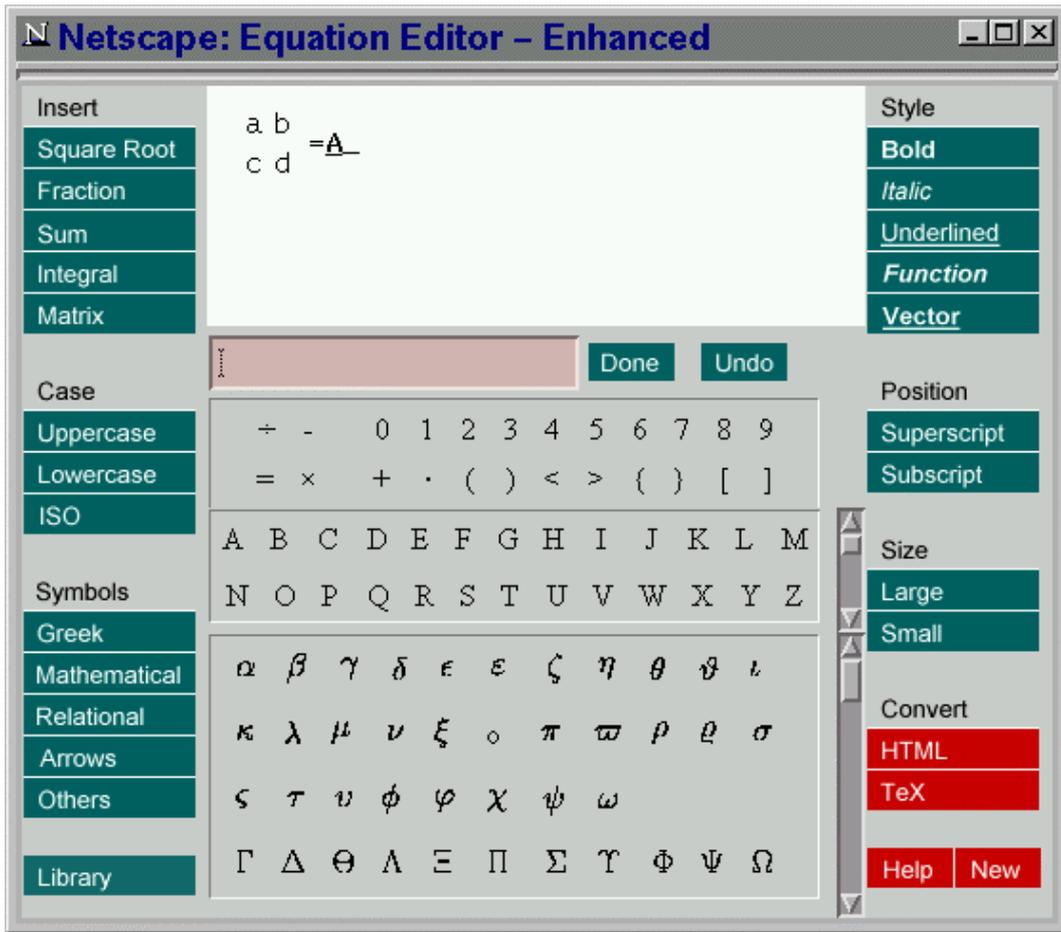
An interactive web-based package for composing scientific equations has been developed at UTS (University of Technology, Sydney) as part of its flexible learning initiatives. As this goes to press it is the only realistic option for producing mathematics for the interactive web applications ("on the fly") without the need for special plug-ins, peculiar syntax, or access to an on-line database of special symbols.

The package is browser based and has an intuitive interface (see Figure 5) and handles symbols, superscripts, subscripts, integrals, summations as well as matrices. The equations get rendered in (what you see is what you get) HTML as they are composed. The final output can be in the form of HTML (Figure 5) or LaTeX or, after server processing of your request, an inline GIF image which can be saved on your local machine or pointed to by its URL on the server.

A novel use of guest book software

Towards the end of the semester one other web-based activity is introduced. It utilises a "guest book" type package to create a student created list of relevant links to the World Wide Web. As part of the learning activity, students are introduced to search engines and how to use them and asked to find a credible URL on the Internet and to *explain* the relevance of their finding to the subject matter. Over several semesters this has developed into a valuable resource for students and teachers alike. A sample of the sorts of contributions made to it under one category of topic is reproduced here:

- Domain Wall Motion has been contributed by Dave *because* it shows examples and excellent graphics as to how domain walls move and examples of where it is undesirable.
- NOVACAP's Technical Brochure: Ferroelectric Ceramics has been contributed by Jenni *because* it provides a good summary of ferroelectric ceramic characteristics and takes the subject just a bit further than what's done in class. It also concentrates on barium titanate, which is of interest at the moment, but discusses the advantages of using other ferroelectric ceramics instead.
- How Things Work: Magnetically Levitated Trains has been contributed by Iain *because* it helps to summarise some of the magnetic section of the subject.
- Superconductor Levitation Movie has been contributed by Budiman *because* it is relevant to our project.
- Magnetic trapping of ultra cold molecules has been contributed by David *because* it answers Evelyn's question about whether all magnets are solids.



Regression Sample shown as html

$$y = a + bx$$

$$a = \frac{\sum x^2 \sum y - \sum x \sum xy}{n \sum x^2 - (\sum x)^2}$$

$$b = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2}$$

Figure 5. Screen grab of the web-based equation editing software control panels, together with a sample of HTML output produced

MagSim: An interactive web-based multimedia development

A number of scientific concepts need to be described **both** in terms of the macroscopic behaviour they exhibit and in terms of the microscopic processes which underlie the phenomena. Genuine understanding of these areas of science requires that the learner move comfortably and confidently from the macroscopic to the microscopic

realms. The causal connections between the macroscopic and microscopic realms are all too often made only superficially with the “complete picture” remaining distressingly unclear.

The magnetic properties of materials are a prime example of this type of macroscopic-microscopic duality. The use of computer simulation to help explain magnetic behaviour by

simultaneous display of microscopic and macroscopic realms has been an ongoing development.^{8,9,10}

An interactive package called *MagSim* was developed originally for Silicon Graphics workstations¹¹ and allowed small groups of students access to the software. The emerging popularity and footprint of the World Wide Web provided the impetus for a rethink of the mode of delivery of *MagSim* to students. The use of web browsers provides platform independent access to the suite of software. The existing simulation code runs as is on the workstations. The relationship between browser and workstation code is illustrated in Figure 6. The main challenge in the conversion process has been to create web browser compatible graphics “on the fly” and return them as an embedded *QuickTime* movie (see Figure 7). Graphic design support¹² was crucial to the production of an interface that was compatible with “lowest common denominator” web browsers.

Fully interactive use of the package has proved to be too slow for regular use, especially for off campus access. A pre-packaged set of animations has been produced that students can then analyse in a web-based assignment/revision class.

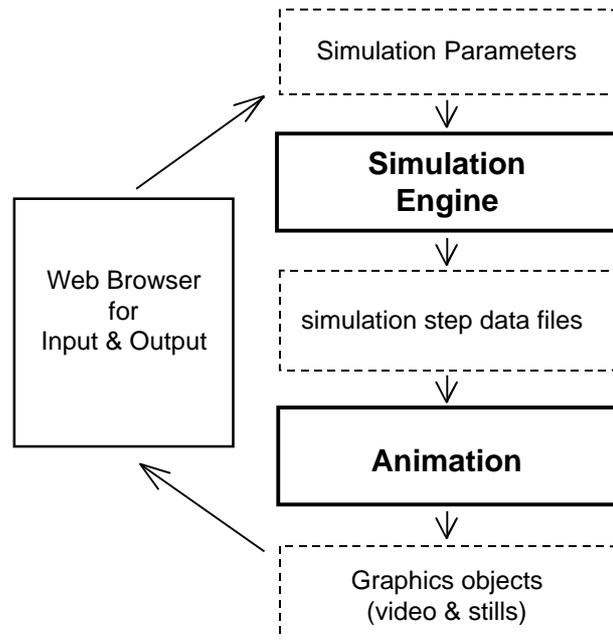


Figure 6. Role of the CGI interface in providing access to and results from the complex simulation software. Output in the form of pictures gets sent back as an animation into the web browser.



Figure 7. *MagSim* video animation used as stimulus in a web-based assignment

Summary

This paper has described several aspects of my activity in web-based teaching in physics. The generic features of a system for supporting the range of facilities required of an on-line teaching space were with the reminder that commercial packages are available that can be used for the purpose. A snapshot of the students that have been involved in these developments has been presented along with the

features and functions of the Virtual Physics Learning Centre that the majority of them were registered for. A strategy to engage third year physics students in on-line discussion of core concepts has been presented. A pair of interactive browser based packages have been developed, one motivated by an identified need in students misunderstanding of magnetism, and the other motivated by the practical issue of communicating on-line using mathematical notation.

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Computer Aided Learning in Undergraduate Physics Teaching

K. E. Johansson

Department of Physics
Stockholm University
P O Box 6730
S-113 85 Stockholm
Sweden

Kej@physto.se

FLIP collaboration

Department of Mechanics
Royal Institute of Technology
S-100 44 Stockholm
Sweden

Department of Physics
Stockholm University
P O Box 6730, S-113 85 Stockholm
Sweden

Department of Physics
Royal Institute of Technology
S-100 44 Stockholm
Sweden

Abstract

To increase the attractiveness and efficiency of physics undergraduate teaching we have implemented the use of computer programs in the learning process in several physics courses. Existing courses have been complemented with computer simulations of physics processes using existing computer programs covering a wide range of physics items. In addition new courses have been designed and implemented exploiting the powerful potential of computer simulation.

Introduction

The introduction of new teaching methods, such as a more systematic use of simulations of physics processes, involves changes in the way physics has been taught and the teaching tools used. Teachers have to get used to a new set of computer programs and the classrooms and lecture halls have to be correctly equipped with computers, display facilities and network connections. The experience of the implementation of Computer Aided Learning in undergraduate physics teaching presented here is based on the work by Stockholm University and Royal Institute of Technology Collaboration, FLIP, Flexible Learning in Physics¹.

FLIP

The aim of the FLIP project is to increase the flexibility and efficiency of physics teaching and to introduce an international character and co-operation into the educational program. This is an important part of making Swedish students internationally competitive and of making our teaching more attractive to foreign students. We have focused our interest on computer programs developed by the Consortium for Upper-Level Physics Software (CUPS)², which cover a wide range of physics items, and the Software Teaching of Modular Physics (SToMP) programs³, which are more complete education packages covering a small number of physics items. The experience we have gained from using the computer in the teaching process has led to the design and implementation of courses where the

use of computer simulations has been an important part from the beginning.

Implementation of CUPS programs

The CUPS programs in Mechanics and Quantum Mechanics have been rather extensively used⁴. The Quantum Mechanics program was introduced and used as a pedagogic tool in the introductory course in Quantum Physics given during the fifth semester of the physics studies. The main part of the course was defined by the existing textbook, which covers the normal topics of a first course in quantum mechanics. The programs were used during the lecture sessions either as planned demonstrations or as illustrative material. The programs were also frequently used during the discussion sessions. The CUPS programs provide a simple way to construct and modify situations that are normally difficult to show with transparencies; e.g. display of different potentials and the solutions to the Schrödinger equations for these potentials, and penetration and scattering of particles of different energies by various potentials. The students were encouraged to explore the quantum mechanics package on their own and many students did.

We have also used the CUPS packages in Mechanics and Waves and Optics. Many of the CUPS programs illustrate, in a very instructive way, phenomena in mechanics and wave motion. In most programs the effect of varying important parameters can be well studied. The programs have also been used to find numerical solutions to more difficult problems, like finding the frequencies of the normal modes of a complicated system of coupled oscillators. Up to now the CUPS programs have mainly been used for demonstrations during the lectures. However, the CUPS programs are also available to the students for individual training and problem solving. The programs and textbooks include many illustrative problems for individual training.

Quantum mechanics for chemists (Computer Chemistry)

The experience from the pedagogical experiment was used in designing new courses given in the spring of 1997 where the advantages of illustrative computer demonstrations were found to be even greater. The result was a course in "Computer Chemistry" given at Stockholm University and the theory part of a course on "Catalysis" given at Chalmers Institute of Technology, Gothenburg. The quantum mechanics course for chemists is completely new and comprises 10 weeks. The part given by the physics-based quantum chemistry group corresponded to three weeks of lecturing and the task was to introduce the students (second year chemistry students with no mathematical or quantum mechanics background) to quantum mechanics and quantum chemistry. The challenge to discuss the consequences of the Schrödinger equation and its application to problems in chemistry with such little time available and to such a mathematically unprepared group of students was very successfully solved using the computer.

This allowed a discussion of the models and of the properties of the solutions and the qualitative aspects of quantum mechanics and was very much appreciated by the students. For the initial teaching of quantum mechanics, the CUPS program on Quantum Mechanics was extensively used. The second part of the course was based on the *MacSPARTAN* program⁵, where the molecular Schrödinger equation is set up and solved at different levels of approximation.

In summary, the most important contributions to the teaching from the use of these computer programs in the Computer Chemistry course has been the flexibility to set up models and to solve them interactively in a discussion form with the students. The computer program brings forward the contents of the solution while eliminating the mathematical intricacies, which can be discussed much more easily at a later stage when the students are ready for it. More details about the course can be found in Reference 4.

Implementation of SToMP programs

The philosophy behind the SToMP packages is quite different from the CUPS programs. The program package is very large and complete, containing a lot of text, background material, illustrations, video clips and interactive exercises and can more easily be used for self studies. However some tutoring is required in order to profit fully from its capacity. The SToMP programs have been used as attractive complements to the standard textbook in the Fields and Waves courses. Three different courses have been given for a total of 160 students. Also the SToMP package on measurement uncertainties has been used in the courses.

Environment for the Computer Aided Learning implementation

A large amount of effort has been devoted to create a constructive and creative environment for the teachers where Computer Aided Learning can be studied and the implementation strategy can be worked out and tested. The introduction of new teaching methods, like a more systematic use of computers, involves changes in the way physics has been taught before and the teaching tools used. We have organised seminars, demonstrations and workshops, very often with invited speakers from the international physics community. We have also constructed the Teaching Development Laboratories to provide a laboratory where new teaching material can be studied. To interest and stimulate the teachers has been one of the main aims of the FLIP project and the creation of a good environment for the development of physics education has been one of the main successes of the FLIP project.

Summary

We have successfully implemented the use of teaching packages like CUPS and SToMP programs as well as

producing our own courses where the use of the computer plays an important role in describing and explaining physical processes. An important part of the work has been the critical study of existing material and selection of the parts that fit in the existing courses. One of the main successes of the FLIP collaboration is the creation of an inspiring environment for the development of Computer Aided Learning in Physics. We have explored and successfully used the computer as a tool in several physics courses at both the Royal Institute of Technology and Stockholm University and have given support to the teachers in their implementation work.

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Learning Computational Chemistry via the Internet

B. J. Salter-Duke
School of Mathematical and
Physical Sciences
Northern Territory University
Darwin, NT 0909
Australia

b_duke@lacebark.ntu.edu.au

M. G. Wong
School of Engineering and Science
Swinburne University of
Technology, VIC 3122
Australia

marg@freon.chem.swin.edu.au

E. J. Lloyd
Victorian College of Pharmacy
Monash University, VIC 3052
Australia

B. F. Yates
Department of Chemistry
University of Tasmania
Hobart, TAS 7001
Australia

G. J. Cross
Water Studies Centre
Monash University
Caulfield Campus, VIC 3145
Australia

Chemistry, and in particular computational chemistry and molecular modeling, is well suited for learning over the Internet using the World Wide Web augmented by other Internet tools. We have developed a series of learning modules which are now used for teaching a Masters degree in computational chemistry offered by three Australian universities in distance education mode over the Internet as well as being used in modified form for final year and Honours year courses. Two techniques play a key role in allowing the student a hands-on flexible approach. Web forms allow access to a variety of computational codes allowing students to run their own data without having to have the code on their own machine and in a more user-friendly fashion than standard batch mode. Web helper applications and plug-ins such as *Rasmol* and *Chime* allow students to investigate molecular structures in ways that they, not the instructor, determine. These developments will be discussed along with pointers to extending these approaches to other areas of chemistry.

The Internet, and particularly the World Wide Web (the web), has been hyped-up as the ideal way for offering flexible education. We have been using web-based materials for three years and some of the advantages and disadvantages are beginning to become clear. We start with a cautionary note as a preliminary to our thesis that the web should be used largely for the things it does well and that it should not be expected to do everything. We then describe some approaches that are particularly appropriate for teaching computational chemistry but have some validity in the teaching of other areas of chemistry. These areas include those such as stereochemistry where visualization is a great aid to understanding the relationship between structure and reactivity and theoretical chemistry where interaction with both local computer programs and remote computer programs with the web can be integrated.

Even though the majority of students, when polled, claim to enjoy learning via the web they still try to print out most web pages. This may be due to the sheer impossibility of keeping large amounts of material in the mind. They then go away and study the printed material, returning to the computer to use the web interactively. When asked about this, they respond that too much time in front of a computer screen may damage their eye sight or give them a stiff neck. These are responses to any intensive computer-based instruction. If students print everything off, then a more cost effective way of delivering flexible learning might be the

traditional approach of sending out study booklets. We prefer to conclude that web materials should contain a lot of activities for which the web is particularly appropriate. One further advantage of the web-based materials over printed manuals and CD-ROMs is that web-based materials can easily be modified, updated with current information or corrected in response to student feedback. In this way the materials are never static. Our considered opinion is that web materials should be used by instructors who are capable of modifying HTML (HyperText Markup Language — the standard method for writing web pages) and even CGI (Common Gateway Interface) scripts. CGI scripts are usually written in *Perl*; a scripting language, although any computer language can be used.

We try to keep our web pages as flexible as possible and include interactive activities which are particularly appropriate for web use whenever these are possible and useful. It is not appropriate to just transfer lecture notes to the web. Our computational chemistry materials were initially prepared with the support of a 1995 CAUT (Committee for Advancement of University Teaching, Australia) Teaching Grant, then trialled with various final year and Honours students, and finally cast in a form which is used to teach a Masters and Graduate Diploma¹ course offered in distance education mode. The web materials here are the main technique for delivering the content, but they are augmented by some written materials and much email contact between the instructors and students. Students are expected to write essays and reports based on the web materials and the interactive exercises where they used the web to carry out computational chemistry calculations. Two techniques stand out as being particularly appropriate for web-based chemistry and it is these we will concentrate on here.

The first tackles the problem of how to get students to do calculations. Computational chemistry involves calculations which require highly intensive use of computer resources and use code that is often extremely large and complex, having been developed over a long period of time by many people. While some of these codes have been adopted — often with a loss of function — to run on the current range of fast PCs, it is impossible to expose students to the full range of computational chemistry techniques if all they have at home is a PC while they study by distance education. There are even problems for internal students: indeed our initial grant application, written in 1994 before the web had become really popular, addressed the problem of students from a group of universities accessing computer codes which for cost and other reasons were only available in one or a few of the universities involved. Cost is also a factor for the home based student since many adaptations of computational chemistry codes for PCs are very expensive, while codes for Unix servers are cheaper or even free.

The current web technology for providing programs is Java, where a program is delivered by the server to the user's browser and run there. Java is a machine independent language so it can in theory be used on all computers. However this requires converting a wide variety of

programs; many very large and written in a variety of languages into Java. This is just not feasible. Even if it were, download times for set up of the programs would be prohibitive. A further problem is that these programs often require large amounts of memory and disk storage space which we cannot be sure the users have available.

The solution is to provide the programs and run them on the server machine. The user enters data into a web page with forms, boxes, buttons and pull-down menus. The data are returned to the server where processing occurs via a CGI script. The script essentially reformulates the data into the form expected by the appropriate program and then calls the executable code to run the program. The output is then collected by the CGI script and returned to the user as a web page. In many cases the executable program takes too long for this to be practical, so the output is collected later by the server and sent to the user by email. The job is also queued to ensure that only one job at a given time is using the server processor and the server disks which have to store large amounts of temporary data in scratch files. Users are able to check the queue to see where their job lies and, if it is running, can inspect the output as it happens.

While users are initially given carefully restricted tasks and view annotated output from the programs to learn how to interpret the output, they can quickly move on to use the programs for any task they themselves devise. These will of course include attempts to complete assignment problems, but is not restricted to them. Even with assignments the students can choose their own way to do them and will often make mistakes in preparing the data. They each learn in their own way.

The only limitations of this technique lie with the server. Will it get overburdened with jobs so the user has to wait hours or days before receiving results? Does the server have to do other things? So far we have not had major problems. Jobs are restricted to a maximum time and memory usage as determined by the CGI scripts. Only users who have authenticated their use with a user name and password can access the web pages that lead to running these large programs. If pressure on one machine gets too high, a simple change in a configuration file can redirect the jobs to a different machine from the main web server. This technique is quite general in that it is relatively simple to change a CGI script to run different data for a different program. Writing the first CGI scripts was difficult for us but now adapting them is fairly simple.

Clearly this technique is not going to be useful in all web education, or even in all areas of chemistry education over the Internet. However, there are areas outside computational chemistry where it is applicable. One such area is environmental modeling. In many other areas quite simple calculations would enhance the learning experience. These could be done either by CGI scripts on the server or by Java applets on the browser.

The second specifically chemical application arises from the visual nature of much good chemistry learning. Chemists have to appreciate the three-dimensional nature of

molecules and explore them from many different viewpoints. Pictures of molecules can be downloaded from the server in the same image formats as used for other pictures on the web, but they have two disadvantages. Firstly too many large image files slow the web experience particularly if downloaded via a slow modem line. Secondly they are static pictures with only one viewpoint. The student cannot explore alternative viewpoints. Animated movie pictures of molecules would partially lessen the second problem but would increase the first problem. The student can still not control the viewpoints and how they investigate the molecule. The current solutions to this problem of visualizing molecules are fairly widely known and are not original to our work. Common solutions are the use of *Chime* (or *Rasmol*) and VRML. Both involve the downloading of a relatively small data (not image) file and the use of extra code on the browser machine.

*Rasmol*² is a molecular modeling program which takes as data the Cartesian coordinates of each atom in the molecule. The molecule is then displayed and the user can, using the mouse and pull-down menus, rotate the molecule in any desired direction or alter the ways the atoms and bonds are displayed. *Rasmol* can be used as a helper application by the browser. The most common format for the atomic data used by *Rasmol* is the PDB (Brookhaven Protein Data Base) format. Such a file has the extension .pdb to its name. The browser is configured so that when a file with the .pdb extension is received from the server, *Rasmol* is opened up as a new window and the molecule displayed.

*Chime*³ takes this process further. The *Chime* code, developed from *Rasmol*, is incorporated into the browser such as *Netscape Navigator* or *Internet Explorer* as a plug-in. When the file with the .pdb extension is received it can be handled in two ways. In the simplest approach a new browser screen displays the molecule which can then be manipulated with the mouse. The left mouse button allows rotation of the molecule. The right mouse button leads to a pull-down menu. Most of the flexibility of *Rasmol* is present. In a more elaborate use of *Chime*, the web page defines an embedded window and initial conditions for the display. In this way a page can display several molecules each from their own PDB files on the screen at the same time. Each molecule can be manipulated in the same way as described above. *Chime* with embedded windows for several molecules is now the preferred technique, but *Rasmol* is still useful for general interactive use and if the user has a browser that can not support *Chime*.

VRML (Virtual Reality Modeling Language) is in many ways more powerful and more general as it is not restricted to molecular models. Like *Chime* it uses a plug-in. A common one for PCs is *Cosmos Player*⁴. Some chemistry applications have recently been discussed by Casher, Page and Rzepa⁵. The great advantages of VRML over *Chime* are the ability to zoom-in on part of the image or manipulate just part of the image. We anticipate a great future for this technique in chemistry web pages, but we have not as yet

included any major use of it in our own materials. Preparation of VRML materials is more difficult than preparation of *Chime* materials and the required plug-ins are not yet as widely available as *Chime*, although this is changing fast.

These visualization techniques allow most of the usage of physical ball and stick kits, along with adding new features. One important new feature is the ability by a click on a menu to change the type of model used. For example a ball and stick display can be replaced by a space filling model based on Van der Waal's radii. For proteins a ribbon or a strand model can replace the atom based models. Each display has its own virtues. The main disadvantage is that the student cannot design their own model but only get what is in the PDB file sent by the server. They can, however, view the model in a large number of ways and their viewpoints are theirs, not the instructors. We are investigating web pages that assist the student in designing their own molecules for display via *Chime* or *Rasmol*.

These techniques are particularly pertinent in computational chemistry where the shape and structure of a molecule is crucial for predicting its properties. Structure, along with energetics and kinetics, are central themes in chemistry and biochemistry so web techniques must be exploited to emphasise this. All molecular diagrams in web pages should preferably be presented as embedded *Chime* images. Students using the material are not forced to move the molecule around, but they might get greater insight by doing so.

A number of other plug-ins or helper applications can greatly improve use of the web for learning. Examples include spreadsheets to access and manipulate data from the web allowing a wide range of exercises and manipulations. Plug-ins are also required for video and audio applications which can enliven the web experience.

Web materials, like books or CD-ROMs are arranged and ordered by the instructor. The techniques described here allow students more freedom. Within some constraints students can define their own tasks and their own learning. The disadvantages of web materials will only be overcome if they contain many examples of these more interactive techniques.

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Computer Based Assessment – The Chemistry Quiz

Steve Walker

CTI Centre for Chemistry
University of Liverpool
Donnan Laboratories
Liverpool
L69 7ZD
United Kingdom

Ctichem@liverpool.ac.uk
<http://www.liv.ac.uk/ctichem.html>

Introduction

This series of programs has been developed at Liverpool over the last three to four years in response to two convergent needs — insistence on a minimum numeric competency from students and a reduction in the amount of staff time involved in assessment. There is evidence that both criteria are being satisfied.

Chemistry Departments have been struggling for some time now with the reluctance of students to carry out even simple mathematical exercises. Physical chemists have borne the brunt of this problem but matters came to a head in Liverpool a few years ago when inorganic chemists realised that a substantial minority could not work out their titrations. The staff agreed that this constituted a skill that all competent professional chemists must acquire and so instituted a test which students had to pass to proceed further in their course. This resulted in the test being re-taken as often as necessary until a pass mark was obtained. The amount of work required of staff in setting and marking as many tests as were required can be imagined.

At the same time, staff in the computer assisted learning facility were turning their attention to the question of computer based assessment and a quiz on volumetric calculations seemed to provide the ideal vehicle for a pilot study. The objectives were:

1. to test the feasibility of examining a large class of students (ca. 100) using the in-house computer network of 15 machines. This would deal with such matters as timetabling, reliability, security etc.;
2. to assess the acceptability of such tests from the student point of view;
3. to assess the acceptability from the staff point of view;
4. to assess the educational effectiveness; and
5. to quantify any resultant time savings.

The program

The major requirement of this program was that, since the test would have to be taken on several different occasions students must be presented with different calculations to prevent prior knowledge conferring an advantage. The CTI Centre provided details of all the available packages, but despite the excellence of some of them, they all failed this criterion. In a typical example, a numeric question and its answer must be pre-programmed with no provision to calculate the answer from the question nor to use random input. This would entail 100 separate numeric inputs for each question together with the corresponding answers to give a different value for each student — clearly time consuming and probably not worthwhile. Accordingly we wrote our own.

The *Chemistry Quiz* (CQ) is a program (now a series of programs) used to test students' competence with the everyday numeric manipulations required in chemistry and is designed to complement the existing range of software available. CQ allows the generation of random input data so that every student receives a different value even when attempting the same question. CQ is designed only for this type of question and makes no attempt to incorporate textual input, multiple choice or other features found in other products. All computations use integer arithmetic to avoid rounding errors, with sensible use of significant figures. Quizzes have been produced covering volumetric calculations, spectroscopy, thermochemistry, particles and waves, and algebraic manipulation.

Modes

CQ may be set up for student use in one of three different modes:

1) Practice mode

In this mode the student is presented with a total of 20 questions chosen at random from all the available question types for a particular quiz. The total of 20 has been chosen to minimise time and resources and to provide a reasonable length of study. In this mode a student may opt to exit at any time or, indeed, to repeat the quiz an unlimited number of times. The student also has the ability to choose a particular question type at any time — useful for tutorial homework etc. *This mode is the default.*

2) Directed Practice mode

This is similar to mode 1) with the exception that the available question types (and their relative frequency) are specified by the lecturer in a file (setup.dat) placed in the same directory as the quiz. This is useful if some of the questions are not covered in a particular syllabus, the class requires extensive practice in a particular method, or the quiz needs to be modified during a course as material is progressively put in front of students. Students are unaware, in practice, of the differences between modes 1) and 2).

3) Examination mode

In this mode, the number of questions, their relative frequency and order are completely specified by the lecturer in the file 'setup.dat'. This file also contains information required of students, such as passwords, and contains pointers to the location of students' answer files. In complete contrast to modes 1) and 2), students cannot exit until they have seen all the questions stipulated (although not necessarily answered!) and when they finish their answers are recorded in '.csv' format for compatibility with spreadsheets.

CQ comprises three parts: **Quizmaker**, which is used by the lecturer **only** to set up a test, a series of **Quizzes** for the students to take, and **Analyser**, which marks the answers.

Quizmaker

The Quizmaker program is installed on the lecturer's own computer. It consists of a number of pages which specify the precise quiz format such as the mode, quiz subject, number of questions, question frequency, type of question, time limit, location of the answer files, and so on. It generates the 'setup.dat' file.

Quizzes

When a quiz file is opened, the program looks for the file 'setup.dat' in its own directory. If it fails to find it then it will proceed in practice mode. At all times the student has the option to look at the correct answer. If the set-up file is found (and examination mode was specified) then the student **still** has the choice of continuing to practice or opting to sit the examination.

In examination mode the student must answer the quiz in the style defined by the lecturer. A particular question can be skipped by clicking on "Next Question". After all the required questions have been presented, the student has the option of reviewing the answers and changing them if desired. This can be repeated as often as required until the student is satisfied. At this point the student should click on "Exit" and the answers will be appended to the data file. If a time limit has been specified then the quiz begins with a reminder to the student that this is in operation. The time remaining is displayed below the question number in minutes. When five minutes are left this display changes colour to red and with one minute to go a message is placed on the screen.

The volumetric quiz

The students have access at all times to a calculator (with the ability to copy and paste into the answer box) and a table of appropriate relative molecular masses (so as not to introduce errors from this calculation). This contains the following question types:

<p>Type 1. Concentration-1. A random weight (from 0.2 to 2 g) of a typical volumetric reagent, chosen at random from a list of 10, is dissolved in water (from 50 cm³ to 1000 cm³). One question is asked: find the molarity of the reagent.</p>	<p>Type 2. Concentration-2. Similar to Type 1. Two questions are asked. A) Find the molarity of the reagent. B) Calculate the concentration of one of the elements in the reagent.</p>
<p>Type 3. Concentration-3. Similar to type 1. Three questions are asked. A) Find the molarity of the species. B) Calculate the volume of solution required producing a molarity of exactly 0.10000, 0.01000, 0.00100 etc. as appropriate. C) As for question B, but with a randomly chosen molarity.</p>	<p>Type 4. Acid/Base-1. Randomly chooses either the standardisation of sodium hydroxide by potassium hydrogen phthalate or of hydrochloric acid by potassium hydrogen carbonate. Unknown molarities are in the range 0.08 to 0.13 with the unknown solution being titrated against random weights of the standard substance. One question is asked: find the molarity of the unknown.</p>

<p>Type 5. Acid/Base-2. Similar to type 4. Three questions are asked. A) Calculate the molarity of the unknown solution. B) Repeats the calculation for a different weight of standard. C) Asks for the weight of standard required to produce a titre of exactly 25 cm³.</p>	<p>Type 6. Permanganate-1. The standardisation of unknown permanganate solutions by sodium oxalate. Molarities are in the range 0.018 to 0.024. One question is asked: find the molarity of the permanganate.</p>
<p>Type 7. Permanganate-2. As type 6. Three questions are asked. A) Find the molarity of the permanganate. B) Repeats the calculation for a different weight of oxalate. C) Asks for the weight of oxalate required to produce a titre of exactly 25 cm³.</p>	<p>Type 8. Dichromate. The standardization of potassium dichromate with either iron(II) sulfate or iron(II) ammonium sulfate. Molarities are in the range 0.014 to 0.019. One question is asked: find the molarity of the dichromate.</p>
<p>Type 9. Thiosulfate. The standardisation of sodium thiosulfate with potassium iodate using starch indicator. Molarities are in the range 0.08 to 0.13. One question is asked: find the molarity of the thiosulfate.</p>	<p>Type 10. Chromium Ore. The chromium is oxidised to dichromate and reacted with an excess of iron(II) sulfate (25 cm³ of ca. 0.4 M). The remaining iron is back titrated with permanganate. One question is asked: find the weight percentage of chromium (in the range 8 to 13%).</p>
<p>Type 11. Calcium Ore. The calcium (25 to 40%) is precipitated as oxalate, dissolved in acid and titrated with permanganate. One question is asked: find the weight percentage of calcium.</p>	<p>Type 12. Argentimetric. Titration of a halide (randomly chloride, bromide, or iodide) against silver nitrate using dichlorofluorescein. Molarities are in the range 0.08 to 0.13. One question is asked: calculate the percentage of halogen in the unknown.</p>

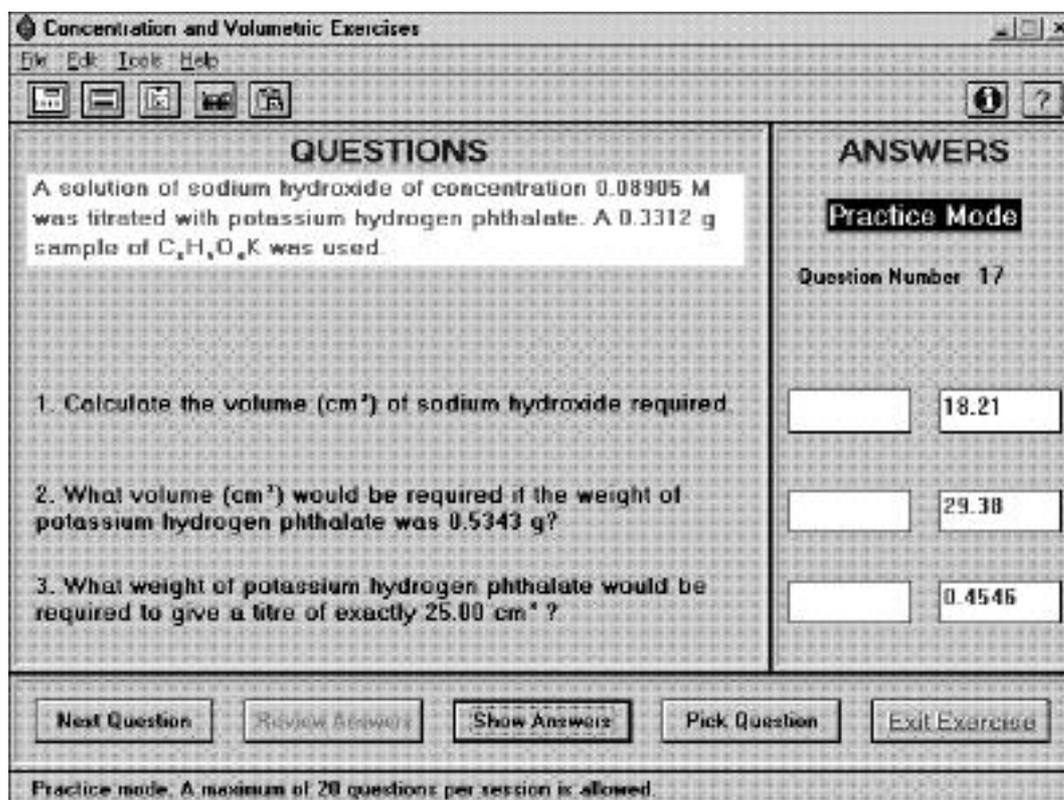


Figure 1. The screen as seen by the student in practice mode with the computed answers displayed

Examination implementation

The volumetric quiz was examined using the following specifications:

1. six questions, one each of types 1, 3, 5, 7, 10, 11 (see above);
2. order of questions: strictly as set down in 1;

3. time limit: 45 minutes; and
4. no passwords required.

The students were given a 'window' of two weeks in which to take the test. They were able to do this at any time within this period and there was no attempt to check for collaboration, impersonation, or cheating, nor was any other traditional exam supervision imposed. The

examination window was scheduled for a period when all students had had time to learn the computer's operation and become confident in the mechanics.

The marking program (Analyser)

A quite separate marking program has been developed which completely automates the marking process and will, if required, generate a final print out suitable for the notice board. This is optional since the answer format is compatible with all spreadsheets and a custom template can be constructed using your preferred program. Analyser allows the accuracy levels required and the mark awarded to be set for each question. The major difference between computer marking and paper marking is that in the former it's an 'all or nothing' process with full marks for a correct answer and zero for one outside the prescribed accuracy limits. A human marker will give partial marks — for example, for writing a correctly balanced equation. Computer marking is thus likely to give lower marks.

Results

The last year for taking the traditional paper test was 1995. This used **exactly** the same question types as those specified above for the computer tests and was designed to be taken in a lecture slot of 45 minutes. The results for 1995, contrasted with results for the following two years, are shown in Figure 2.

Without making any attempts to analyse these data, the implications are clear. The major reason for the

improvement is practice. In the allowed fortnight, students spent the first week practising and only attempted the test when they felt confident. The end result, whatever the means, is that the class can now carry out their volumetric calculations with confidence. Conversely, since there is no evident improvement in students' basic mathematical skills (from tutorials in the remedial mathematics course), it could be that they are simply being trained to carry out these types of calculation.

The time taken to prepare, invigilate, and mark an examination is now 10 minutes compared to approximately 20 hours for the series of paper-based tests. Needless to say, this is extremely popular with staff. Of course, it ignores the time required to write the programs and staff time devoted to running the computer network.

Students are generally supportive although it's difficult to extract anything sensible when asking their opinion of examinations. They like to practice, they like the two-week window and they like to be trusted. The only genuine negative note concerns their inability to indicate their thought processes and to add textual comment to their answers (a bonus as far as staff are concerned!). It may surprise some that they made no attempt to work together (there was, they said, insufficient time for chat), nor to personate nor, indeed, made any attempt to cheat in this completely unsupervised examination. For 1997 (but not 1996) the computer classroom has been fitted with a remote surveillance camera for security reasons and spot checks confirmed that serious individual work was carried out.

Paper	1995 First test	81 Candidates	27 Fail (3 absent)	Mean mark 52%
	1995 First resit	26 Candidates	16 Fail (1 absent)	Mean mark 50%
	1995 Second resit	16 Candidates	2 Fail	Mean mark 55%
Computer	1996 First test	101 Candidates	11 Fail (3 absent)	Mean mark 72%
	1996 First resit	10 Candidates	1 Fail (withdrawn)	Mean mark 65%
	1997 First test	91 Candidates	7 Fail (3 absent)	Mean mark 73%
	1997 First resit	1 Candidate	6 Fail (absent)	

Figure 2. Examination results for three successive years: 1995 when traditional paper tests were given, and 1996/7 when computer tests were given.

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<http://science.uniserve.edu.au/>

Computers in Teaching Initiative



Since 1988 and the establishment of **Computers in Teaching Initiative** (CTI) centres in Britain, there has been a substantial increase in the use of computers as teaching tools. There are currently 24 CTI centres, funded by The Higher Education Funding Councils for England, Scotland, and Wales, and the Department of Education for Northern Ireland. These centres cover a wide range of subjects: the centres for science are distributed between the University of Surrey (Physics), the University of Liverpool (Chemistry & Biology), with Mathematics at the University of Birmingham.

The centres' brief is:

- to support academics who wish to use computers or other educational technology in their teaching; and
- to act as an information resource and centre for expertise for the computer-aided teaching of science.

CTI Centres also maintain databases of resources for computer based teaching, most of which have been reviewed by lecturers in the field, and publish a regular newsletter. Contact with institutes is maintained through a series of frequent one-day workshops and site visits where interested educators can gain hands-on experience with a selection of the latest teaching software. For those educators who are unable to attend the workshops or who wish to browse the available software at their leisure, CTI Centres maintain Web-accessible databases which contain a large amount of teaching software, both commercial and shareware. Furthermore, subject-specific mailing lists are available to all teachers for open discussion, e.g. of computers and their impact on teaching techniques.

<http://www.cti.ac.uk/>

Council for the Renewal of Undergraduate Education



The **Swedish Council for the Renewal of Undergraduate Education** was established by the Swedish Parliament on 1st July 1990, and became a permanent National Agency in 1993. Since 1st July 1995 the Council is an integral part of the National Agency for Higher Education.

The purpose of the **Council for Renewal of Undergraduate Education** is to promote and support efforts to develop quality and renewal of undergraduate education. The three main activities of the council are:

- to award grants for development activities;
- to collect and disseminate information on planned, current, and completed development activities of a fundamental and innovative nature concerning undergraduate education in Sweden and abroad; and
- to evaluate the development activities the Council has funded.

Some specific objectives of the Council are to:

- support the integration of environmental studies in Swedish undergraduate education;
- support changes in curricula and pedagogy in Engineering and Natural Science programmes in order to recruit more female students to these programmes;
- support the use of IT in teacher training; and
- finance a Teacher Exchange Programme.

Currently funded projects include "Hypermedia and Communications for Active Learning", "New Forms of Assessment in Mathematics and Computer Science", "Interactive Distance Education in Multimedia" and "Computer-Assisted Education in Radiographic Techniques for Dental Students".

<http://www.hsv.se/english/>

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The publication series "Högskoleverket Studies" includes studies and analyses commissioned by the Agency. Their contents do not necessarily reflect the view of the Agency.

Högskoleverket Studies 1998:9 S
(Högskoleverkets skriftserie)
ISSN 1400-9498
ISRN HSV-SS--98/9--SE

The National Agency for Higher Education (Högskoleverket) is a central authority for matters concerning institutions of higher education. Its tasks include evaluation and accreditation, carrying out quality audits, developing higher education, research and analysis, supervision, international questions and study information. It is also responsible for coordinating the Swedish university computer network, SUNET.

 **HÖGSKOLEVERKET**
National Agency for Higher Education