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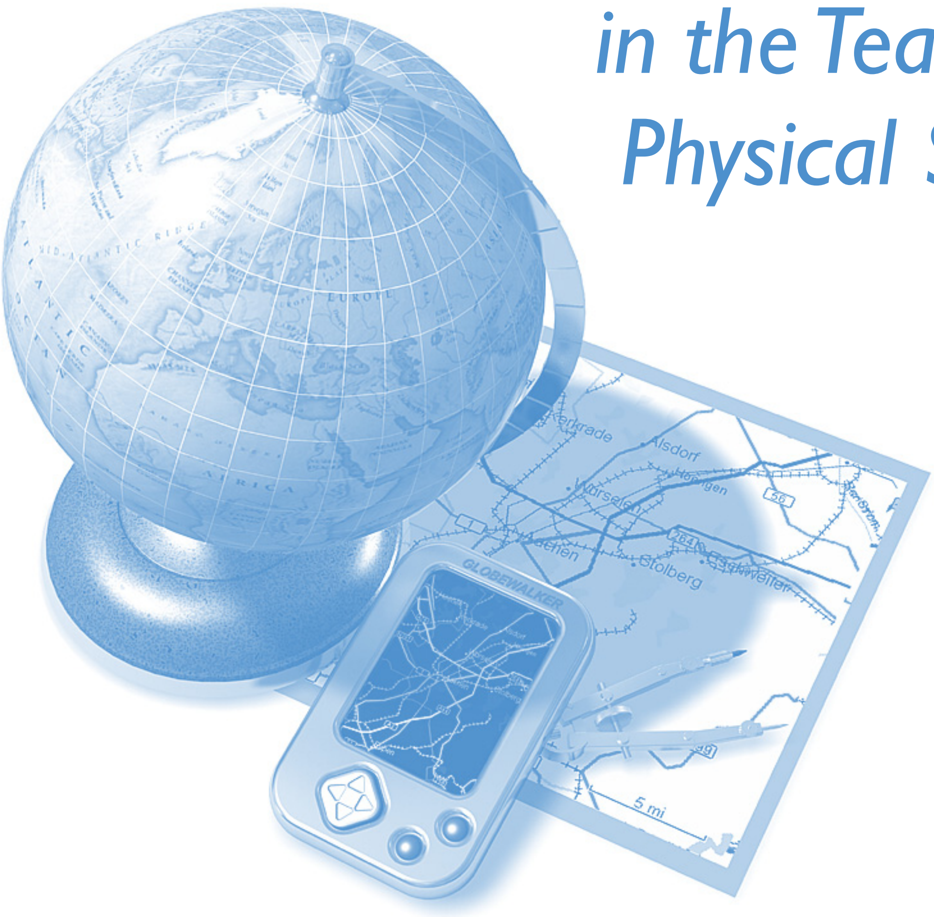
New Directions

in the Teaching of Physical Sciences



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in association with
πCETL, The Physics Innovations Centre for Excellence in Teaching and Learning

Editorial

The first issue of *New Directions* was issued in May 2003 and comprised 17 articles.

In this this issue we present a series of 'reviews' of topics in physical sciences education and educational research written by 'expert' practitioners. The publication also includes 'communications' which arise from a general call for contributions from the physical sciences education community and invited reports from the funded projects working in the physical sciences education arena. In order to increase the provenance of the journal all submissions to *New Directions* are peer reviewed at both the initial and the final submission stages. Once again, the Editorial Team at the Physical Sciences Centre (Roger Gladwin, Tina Overton and Paul Chin) has been pleased to work with Derek Raine at Leicester University (now in association with πCETL, The Physics Innovations Centre for Excellence in Teaching and Learning) on this issue.

In this issue review articles provide comprehensive coverage of e-learning (including the use of e-voting systems and online learning), an overview of the situation with Outreach in the physical sciences plus the use of virtual learning systems and computer assisted assessment in student learning. We also have amongst the communications; subject specific topics (eg molecular modelling in chemistry), the application of context based learning in practicals and in groups plus the use of problem based learning in physics. For the development of skills there is coverage of an Adult Learners course in controversial aspects of science, a course designed to develop enterprise skills in students and a context-based system developing ideas in 'green' chemistry.

We hope that our reviews will keep readers updated on areas of broad interest and that some aspects of the work described in the communications is of use to you in your teaching. *New Directions* will now become a more regular publication and we and hope that you will consider making a contribution to a future issue.

New Directions is a topical journal published by the Physical Sciences Centre in association with πCETL, The Physics Innovations Centre for Excellence in Teaching and Learning

The journal is issued in paper and electronic formats once per year. It is intended for teachers, researchers, policy makers and other practitioners in physical sciences education.

An editorial board reviews all submissions.

The journal is free of charge to academics in UK higher education institutions. Subscriptions are available for those outside the UKHE sector who wish to receive the paper version. Contact the Centre for details.

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Contents

The use of electronic voting systems in large group lectures: challenges and opportunities

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In its simplest form, these questions may be employed to simply break-up the lecture, to regain audience focus and attention and as a mild diversion to the main business of the lecture time around halfway through.

Abstract
We describe pedagogical, technical and operational issues associated with the introduction of an electronic voting system into large first-year undergraduate lectures. The rationale for doing so is to transform the lecture experience from a one-way transmission of information in to a two-way conversation between lecturer and students, mediated by the technology. We discuss some of the logistics involved, such as choice of handset, cost and siting within a lecture theatre as well as the aspects of pedagogy, such as the requirements of a good question for these interactive episodes. We present a number of possible use scenarios and evaluate student and staff experiences of the process.

Introduction
"Despite the changes in the learning environment, teaching methods do not appear to have changed considerably. Initial findings from research suggest that many staff still see teaching primarily in terms of transmission of information, mainly through lectures."
Dearing[1]

The lecture is still the mainstay of university teaching. Its origins can be traced back in history, to when reading aloud to a group addressed the fundamental bottleneck in learning and teaching (the availability of books). Despite the enormous changes that have taken place over the last generation in terms of the size, diversity, expectations and career choices of the student cohort that come to University, the role of the lecture in scientific disciplines has remained largely unchanged. The traditional lecture, however inspirational it might be, is essentially a one-way transmission of information to the students, an exposition of the course material, mapped out along a carefully constructed A-Z of the course syllabus.

Concurrent with the shifting topology of the student landscape has been the explosion of computing and information technology to its present, almost ubiquitous state. The application of this within higher education has in general lagged behind social contexts. Compounding this lag is the fact that our students are now 'digital natives' -- exposed to computing in education from an early age – whereas most of us (however enthusiastically we adopt) remain 'digital immigrants'[2]. All of these factors add to the inertia that ensures, by and large, lectures continue to function in 'transmission' mode. This is especially true for large classes (>100 students). As Flowers has put it "Why Change? Been doin' it this way for 4000 years"[3]. Here, the pervasive influence of Information and Communication Technologies (ICT) can actually have a detrimental effect; a lecturer can easily make a presentation from a set of *PowerPoint* notes and after the lecture deploy the same notes on the World Wide Web. If the students perceive the net worth of the lecture as simply acquisition of the notes, and these notes are available in their entirety on the Web, they may well not attend.

The challenge is, therefore, to try to actively engage the students in the lecture, to develop it to be something more akin to a two-way conversation than a one-way transmission of information. Large classes present a particular problem here by virtue of their very size; one is simply precluded from striking up an interactive conversation with a hundred or more students.

This paper presents a review of one of the ways in which the use of technology can be used in a lecture context to mediate interactive engagement; via handheld, remote devices used to vote on questions, similar to systems popularised in TV shows such as *Who Wants To Be A Millionaire*. Based on our own recent experiences in Edinburgh, which over the last year has seen this electronic voting system used in three large first year undergraduate classes, we consider both practical and pedagogical issues associated with incorporating this methodology into the curriculum. The paper is organised as follows: we first summarise the pedagogical rationale that suggests interactive engagement is an essential ingredient to encourage deep learning. We then consider practical issues of hardware, cost and installation before considering the pedagogical aspects of what constitutes a good question. We highlight a number of possible use scenarios for these systems and also what we have learned from an extensive evaluation of both students and staff experience.

There is already considerable activity with these systems within the UK. Our focus here will be on the application within the Physical Sciences. Three invaluable resources stand out as information goldmines. The first is the online material maintained by Steve Draper from the Department of Psychology at the University of Glasgow[4]. The second is the JISCMAIL mailing list on electronic voting systems[5]. The third is the collection of resources at EDUCAUSE on the utilisation of ICT in higher education in the US, in particular the research bulletin devoted to transforming student learning with classroom communication systems[6].

Pedagogy: interactivity as the essential ingredient

"The complex cognitive skills required to understand Physics cannot be developed by listening to lectures any more than one can learn to play tennis by watching tennis matches."
Hestenes[7]

Few academic practitioners would quibble with the notion of wanting to foster an environment where student learning is 'deep' rather than 'surface'[8], enabling them to construct meaning rather than merely memorise facts. One characteristic of deep-learners are well-developed 'problem-solving skills', equipping the deep learner with the ability to tackle unseen problems beyond the confines of the presentation of the original material. McDermott[9] has termed it "meaningful learning", connoting the ability "to interpret and use knowledge in situations different from those in which it was initially acquired". Development of such higher level skills is also one of the most difficult elements to 'teach'. Student activity offers a pathway to promote the processes of deep learning and develop student proficiencies in doing it spontaneously. In active learning (which has been termed "interactive engagement" by the Physics education research community) the student acts out the higher level cognitive processes of questioning, reasoning, organising and integrating within the subject context. The inclusion of peers in the process, through discussion, generates *inter*-activity. On a superficial level, such interactivity can address the attention span limit and can make the lecture a more enjoyable experience for students. On a more substantive level, engagement with the material and its underlying concepts has been shown to have a profoundly positive effect on student learning.

Hake[10] has presented results of a six thousand student survey, assessing the efficacy of (differing elements of) interactive engagement in teaching as compared to more 'traditional' methods of instruction. The testing instrument has generally been one or both of the two diagnostic tests developed in the US as a measure of proficiency of understanding of fundamental concepts in mechanics: the Force Concept Inventory (FCI)[11] or Mechanics Baseline Test (MBT)[12]. His bottom line conclusion from a statistical analysis of the data is that the use of interactive engagement strategies "can increase mechanics course effectiveness well beyond that obtained with traditional methods". Though much of the work has been in the area of Physics, it seems that the applicability of these conclusions is not limited to this discipline[13,14], but can have an impact across many courses with challenging concepts. A recent paper in the domain of computer science has echoed these findings[15]. In addition, the wide-ranging list of subject areas this methodology is currently being applied to is further evidence, however anecdotal, of its effectiveness[4]. Use of these methods provides important feedback to all concerned. For staff, it enables the cohort's collective understanding to be gauged and for the students it allows formative assessment of their own progress.

Logistics: hardware, cost and siting

"Electronic voting systems typically comprise four elements: a tool for presenting lecture content and questions, electronic handsets, receivers that capture student responses and software that collates and presents students' responses"
Kennedy and Cutts[15]

There is now a bewildering array of vendors who can supply hardware, software and handsets (see Draper's pages for an up to date list[16] and this survey for use in secondary schools[17]). A critical decision to be taken relates to the way the handsets transmit to the receivers; infra-red handsets generally cost much less (at least half, possibly a third the price) than those using radio-frequency communications. The downside to the infra-red hardware is that they are less reliable, need a receiver per 50 or so handsets, and these receivers must be carefully positioned around the lecture theatre to maximise the opportunities to collect all the votes in as short a time as possible.

In Edinburgh, the large class sizes determined that we bought the cheaper of the two alternatives; an IR-based system from GTOCalComp known as PRS (Personal Response System)[18]. In the summer of 2005, the cost of hardware (12 receivers, 400 handsets, adapters and brackets) was approximately £14,000. (This is to be compared to an approximate cost of £21,000 for the same number of radio frequency handsets.) We evaluated two different handsets on trial; the PRS ones were not ideal as there was no clear signal *on the handset* that the student had voted. On the alternative handset that was tested, there was a light to indicate that a vote had been successfully cast. However this handset also looked and felt far less robust than those of the PRS design. As always, these choices amount to a compromise and the need to match the educational requirements to the capability of the system. Our method of use was restricted to single-vote answers to multiple choice questions (MCQs), which we address shortly. There are far more sophisticated handsets (currently all RF) allowing, for example, text entry. There is the added steady-state running cost to be included, which we estimate at approximately 5% for lost or broken hardware, batteries etc.

Our IR handsets have come to be colloquially called 'clickers' (a nickname that originated in the US, and more than once has resulted in the confusion to prospective adopters that they 'actually click'!) IR clickers must have a clear line of sight to a single receiver; signals cannot pass through desks or the heads of people in front of you. This dictates that the receivers (we have used 4 in series for a class of 250, 7 for a class of 350) are mounted in an elevated position, well-separated from each other. In the theatre that accommodates 250, we have placed two at the front of the class, one either side of the teaching wall and two halfway up the lecture theatre, one on either wall. We instruct students to aim for the one closest to them, even though that might be (in true airline-safety-briefing style) behind them.

All systems come with software to collate and display student votes, some (eg the PRS software) with a plug-in for Microsoft *PowerPoint* that enables questions to be embedded within a slideshow and automatically started. We have found one needs the entire display screen to project a response grid which enables the students to identify that their vote has been received. The display of the question on which the students are voting, which clearly must be visible during thinking time, necessitates the use of second screen, overhead projector, or board.

The logistics of providing the students with handsets must be considered. We issue handsets at the beginning of the course and collect at the end, thereby avoiding the loss of valuable lecture time with distribution and collection of handsets. As the adoption of this as a lecturing technique becomes more widespread across other Schools in the College (akin to Departments within Faculties), we are investigating a centralised service of dispensing and collecting the handsets. We refrain from detailing the exact mechanics of operation of an electronic voting episode within a lecture (several clear accounts exist elsewhere[19], including a JISC-produced Innovative Practice case study video[20] and an EDUCAUSE podcast[21]). Photographs of the handsets and the lecture theatre set-up are shown in Figure 1.

Figure 1: Photographs of the handsets used in Edinburgh and a lecture theatre in use

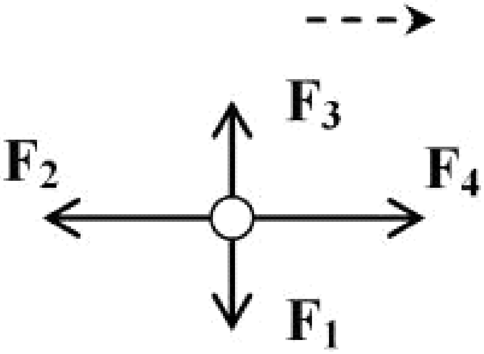
Pedagogy again: what makes a good question?

"Although multiple choice questions may seem limiting, they can be surprisingly good at generating the desired student engagement and guiding student thinking. They work particularly well if the possible answers embody common confusions or difficult ideas. "

Wieman and Perkins[22]

We have exclusively used multiple choice questions (MCQs) as interactive engagement exercises within our lectures in Edinburgh. MCQs have their supporters and opponents, but for us this was a matter of practicality. We have accumulated (over a period of several years) a bank of some 400 MCQs relating to a first year Physics course in the classical study of space and time. In fact, in previous years, we have operated a low-tech version of the interactive episodes in lectures in which students used three coloured cards to indicate their response to MCQs. There are many reasons why the electronic system is better (see for example the student quote within the 'Evaluation' section) but using the coloured cards system over time has provided us valuable insight into what it is that makes a 'good question'.

Four forces, F1, F2, F3 and F4 are exerted together on a hockey puck. The puck moves at constant speed along a straight line in the direction of F4. The arrows in the accompanying figure represent the directions of the four forces but not their magnitudes.
Which of the following relationships represents best how the magnitudes of the four forces are related?



a. F4 = F2 and F3 = F1.

b. F4 = F2 and F3 > F1.

c. F4 > F2 and F3 > F1.

d. F4 > F2 and F3 = F1.

e. F4 > F2 and F3 < F1.

Response Summary

Answer	Value	Frequency Distribution
-	0%	5
a	***100%***	***13***
b	0%	0
c	0%	0
d	0%	56
e	0%	0

Figure 2: Sample question and response profile, illustrating the overwhelming misconceptions that persist about classical descriptions of motion and forces

A good question is one where a spread of answers might be expected or where it is known that common misconceptions lurk. A poor question, by contrast, might be a deliberate trick question, or one that is distracting to the material at hand. An excellent example that evidences such misconceptions is illustrated in Figure 2 (actually taken from a diagnostic test given to entrant students at Edinburgh). Not only did the majority of the students who answered the questions answer incorrectly, they all chose the same incorrect answer. Such unanimous misunderstand-ing is very rare and in this instance can be traced back to elucidate the misconception that guides student choice: in this case the pre-Newtonian view of 'motion-implies-a-force'.

Our questions tend not to be overly numerical; any mathematics required is at the level of mental arithmetic only. Instead, they focus on concepts and the testing of the understanding of such concepts. The Physics Education Research (PER) community in the US has a long tradition of articulating the key requirements of and developing excellent MCQs for use in Physics. Developments have stemmed from Mazur's book a decade ago[23] describing a methodology known as Peer Instruction (to which we return later), to the Project Galileo website that Mazur created to collect many of these questions[24], to recent reports developing and extending Mazur's ideas[25]. The widespread adoption of Mazur's approach has percolated upwards from classical and introductory mechanics and kinematics[26] into more advanced topics in Physics[27] and sideways into Chemistry[28].

Closely allied to the question of 'What makes a good question?', and already hinted at in the previous paragraph, is 'Where do I get good questions from?' It is undoubtedly true that many people harbour collections of such questions locally. The annual marking of exam scripts is a good hunting ground for persistent misconceptions. Nearly all undergraduate text books now come with end-of-chapter questions of this type, many offering the full online provision of formative and summative testing mechanisms[29]. This is a clear example where the growing digital object economy can prevent reinvention of wheels; the challenges are to be able to (a) discover resources and (b) interoperate different resource formats where necessary. Substantial local activity has been undertaken in the Physical Sciences Centre recently with this in mind; our own development project[30] to produce a browse-able library of MCQs for selective download in different output formats; and the Centre's QuestionBank project aim to facilitate storage, sharing and interoperability of these (and other) resources.

Use scenarios

"Electronic classroom response systems....are merely tools, not a 'magic bullet'. To significantly impact student learning (they) must be employed with skill in the service of a sound, coherent pedagogy. This is not easy."

Beatty et al.[25]

We have employed these interactive question episodes in a variety of different ways throughout our first-year Physics and Biology courses and we present some of these as potential use scenarios, which illustrate a number (but by no means an exhaustive list) of the ways that they can be used during lectures. The four scenarios that we outline represent progressively increasing departures from the traditional lecture format and similarly, can be thought of as progressively more challenging to introduce from the perspective of the lecturing team. We believe there is good justification for a mixed mode of use, a point we return to in more detail in the following section. We make no reference here to more complex uses of the technology, for example the handsets that allow transmission of text answers rather than simple numerical choices. Nor do we report the use of these techniques to serve as preparation for examinations[31].

In its simplest form, these questions may be employed to simply break-up the lecture, to regain audience focus and attention and as a mild diversion to the main business of the lecture time around halfway through. Questions need only be loosely coupled to the course material (if at all), and are particularly suited to ice-breakers for a class new to this methodology in lectures. Sample questions include polling the age profile of the class, the subject study level at school, what the class has found most difficult / enjoyable etc. Clearly such questions cannot be used too frequently, otherwise the class will perceive them of little value and engagement with the process will wane. They are, however, particularly useful in familiarising the students and staff in the use and operation of the system.

A slightly more sophisticated and beneficial use of these episodes is to serve as a refresher or test of understanding of key points from material previously covered. An example would be to use a question at the beginning of a lecture, addressing material covered at the last lecture, potentially several days ago. This serves the dual purpose of 'heads-on' engagement of the student with material from the start of the lecture, and as a tool for the lecturer to gauge where the class is with regard to recall or understanding of previous key material. Wit[32] has described such an approach and the subsequent actions of the lecturer in the light of student responses.

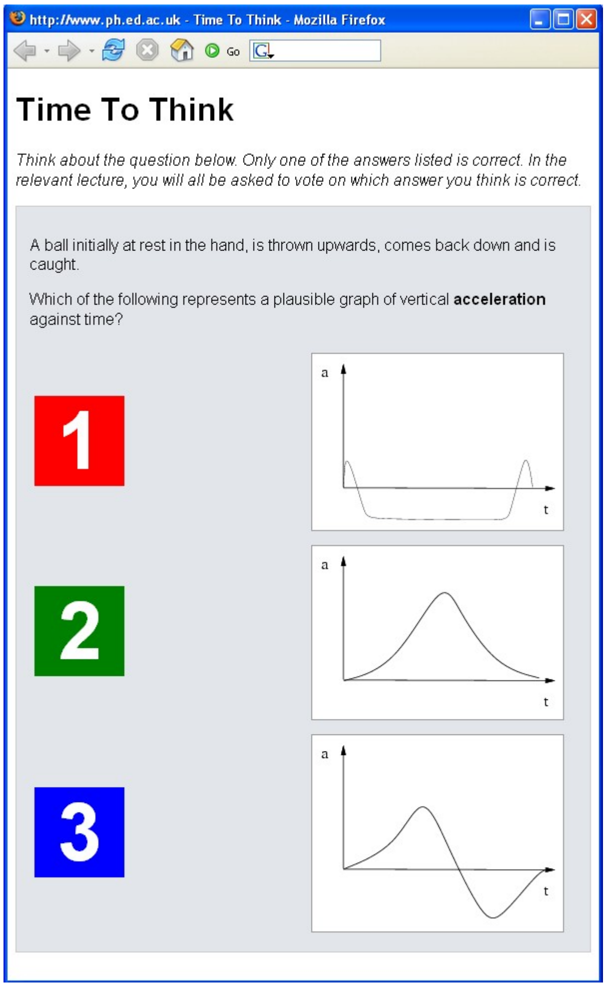


Figure 3a

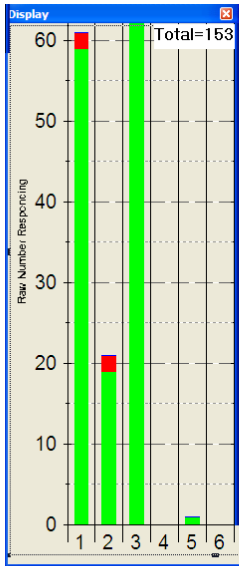


Figure 3b

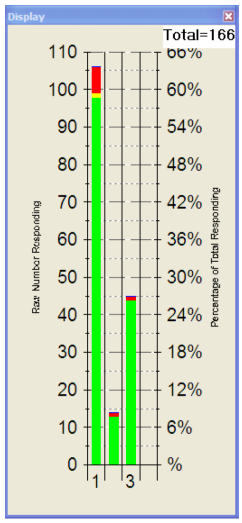


Figure 3c

Figure 3: A sample question (a), polled student response (b) and re-polled response following a few minutes discussion between students, directed by the lecturer (c).

Progressing further along the scale of complexity brings us to the use of these questions as a vehicle for peer instruction[23], capitalising on the social context of discussion and peer interaction. The process for one of these episodes is that a question is posed and voted on individually. Following display of the class responses, students are invited to talk to neighbours and defend or promote their own viewpoint and why they think it is correct. The class is then re-polled and the revised response distribution is displayed. This approach has been extensively used by Jim Boyle in Mechanical Engineering at Strathclyde[20], for which the physical layout of the lecture theatre was altered to foster small-group discussion, using crescent-shaped desks seating four students.

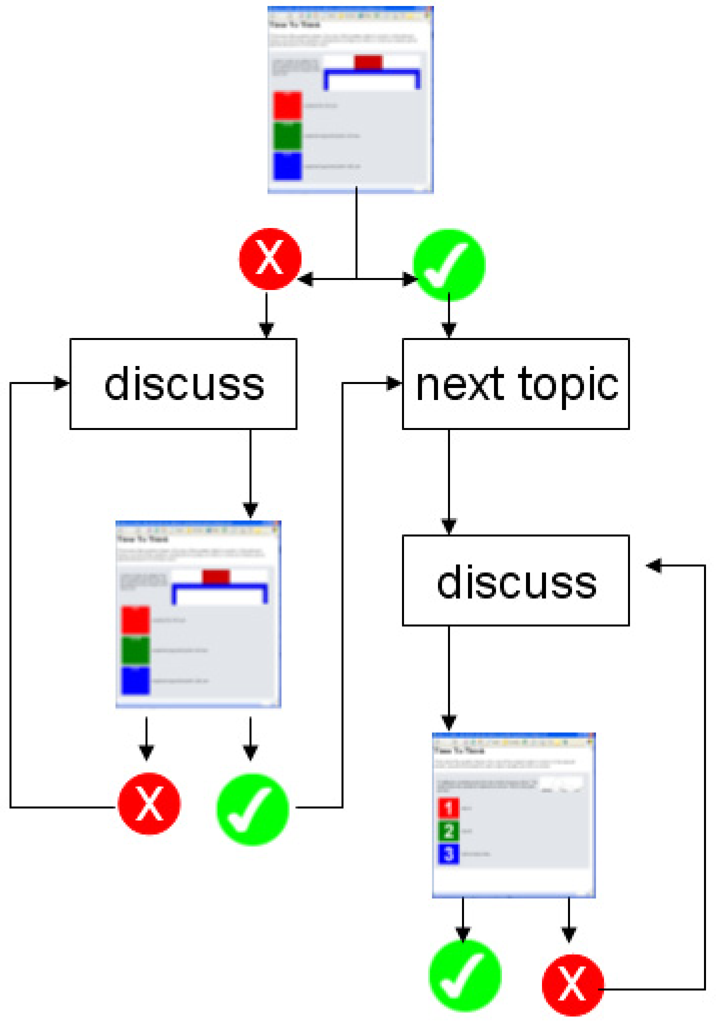


Figure 4: A schematic of the use of questions to drive contingent teaching

The results from our own experiences using this method are illustrated in Figure 3. The question (Figure 3a) is polled (answer 1 is correct) and the initial response histogram is shown in Figure 3b. The class was then invited to discuss responses with each other and re-polled, the results of which are shown in Figure 3c. There is a significant swing towards the correct answer. The misconception implied by answer 2 is retained for a small proportion of the class and subsequent discussion of the problem highlighted why the incorrect answers were wrong. This is, for the lecturer new to this methodology, a potentially disruptive experience; letting go of the control of the lecture for a couple of minute's free discussion by students. In addition, an episode of peer instruction such as this begins to occupy a non-negligible fraction of the lecture time (perhaps 10 or 15 minutes). This has knock-on consequences for coverage which we return to shortly.

The final use scenario is what Steve Draper has termed "contingent teaching"[19], where the interactive engagement episodes act as branch points in the lecture. Subsequent progression beyond these points is contingent on the response from the students. A question which, for example, 80% of the students get wrong would indicate either a fundamental misunderstanding associated with the material, or a lack of clarity in the exposition of it, or both. It would be negligent to pass over this without further comment and perhaps re-polling of the same or similar question. A schematic of how such contingencies might unfold is illustrated in Figure 4.

In this respect, the lecture truly becomes a two-way experience, a conversation between staff and students, mediated by the technology. The students collectively influence, perhaps even determine, the route that the lecture takes through the available pathways of material and questions. The thought of leading such sessions might be deeply uncomfort-able to some staff and it is true that a great deal of care and planning (and limiting the number of possible contingencies) is needed to run these lectures effectively. It can be both an unsettling and, when it works, exhilarating experience to teach in this manner. Beatty et al.[25] have termed this method of instruction "Question-Driven Instruction" and present an explicit model detailing pedagogical goals and the mechanisms that achieve these.

The more complex these episodes within a lecture generally become, the more time they will occupy. It is important not to rush through them, but to give the class adequate thinking time (usually we choose about 2 minutes, but increase or decrease where appropriate). A cycle of peer instruction can take 10-15 minutes, perhaps longer if it is preceded by an orientation to the problem or topic at hand. This is a substantial fraction of the lecture slot and it raises issues of what to do about the content that would normally have been covered. Two equally unsatisfactory extreme views are (i) to try and shoehorn material in, or (ii) to not be concerned about lack of coverage. We have found that if the lecture time is spent not covering the traditional A-Z of the course material, this material must exist elsewhere and be able to be integrated into the course. This may take place in other teaching activities: workshops[33] or tutorials, for example. Or it may be located in students' self-study time, in the form of online resources, or a textbook. We have made use of the concept of a 'learning contract' with the students. The agreement made at the start of the course is that if we do spend appreciable amounts of time on interactive engagement in lectures, their part of the bargain is that the displaced content is covered in other activities, be it other face-to-face teaching times, or in self study.

Evaluation

"Our most important piece of advice….. is to pay critical attention to what happens when you do it. Your students are your best teachers"

Beatty et al[25]

One the most difficult things to evaluate after using this methodology is the quantifiable effect it has on student learning. The absence (or perhaps ignorance?) of such data, and a reliance on more qualitative evaluative instruments unfamiliar to those with a research-based scientific background, makes it difficult to persuade detractors of the technique's efficacy. However, there are studies that attempt to correlate employment of this technique with assessment performance. The extensive study by Hake[10] provides compelling evidence for the effectiveness of interactive engagement as a broad-ranging premise to improve student learning. Kennedy and Cutts[15] have found a positive association between usage of an electronic voting system and learning outcomes tested in course assessment. El Rady[14] has found a similar positive association. However, caution should be exercised before proclaiming this as a general finding. There are still many variables, the effects of which may be subtle and resolved only at the local level of course delivery, modes of use of these exercises, assessment methods etc. These may contribute to or even swamp any effects that can be isolated to arise solely as a result of using this methodology.

Our own investigations of the correlation between lecture attendance in a first year Physics class (more accurately 'participation', as evidenced by a recorded vote from a handset) with end-of-course examination performance has yielded a positive correlation, albeit rather weak (R^2= 0.18). The scatter illustrates the inherent problems collapsing multi-dimensional data from an extremely heterogeneous cohort onto a one-dimensional scale, analogous to using a one-dimensional radial distribution function as a measure of three-dimensional liquid structure[34]. Furthermore it is not clear if performance in the exam is related to lecture participation via cause or effect.

We have extensively evaluated the attitudinal aspects of the use of this methodology, from the perspectives of both students and staff. A dedicated section in the end-of-course student questionnaire, using a combination of Likert-scale and free text questions, has generated plentiful and informative feedback. This was supplemented by focus groups with small groups of students. In the Physics course that had previously utilised the same interactivity with coloured cards, the student response was almost unanimously positive, with the clickers often rated as one of the best things about the course.
One difference between using clickers to coloured cards is the anonymity it confers on the student and the ease with which the whole-class profile is visible immediately following a question. The following quote, from a Physics student asked about how they felt when getting an answer wrong, exemplifies this:

"At least no-one knows you got it wrong. You can still sit there, you are still motivated, you are not like 'Oh, everyone saw that I got it wrong, I'll just crawl into my corner and die"'

The general objective of increasing student involvement and engagement with the material was widely recognised as a positive feature by the students:

"The questions make you actually think about what the lecturer has just said, which helps 'cause sometimes it just goes in one ear and out the other"

It would be misleading for us to conclude that this is has been an entirely successful venture without problems. In fact, deployment of this methodology across the three large courses (two in Physics, one in Biology) has not always been straightforward, but has always been useful. Based on firsthand reflections on the process, incorporating the feedback from other staff and students involved, we can offer some tentative 'Do's and Don'ts' for people thinking of or actually taking their first steps down this road. Many of these suggestions arise directly as a result of our own (sometimes uncomfortable) experiences. There probably is no single universal recipe for guaranteed success, only pointers that can contribute to the likelihood of effective incorporation. Thus we suggest the following guidelines and advice:

Well before the lectures

- It should be recognised that incorporating this technique will take careful planning; do not under-estimate the time and effort taken. It is not an out-of-the-box solution.
- It is important to consider the requirements and impacts of the employment of this technique in all aspects of the design and operation of the course; it is not a simple add-on.
- Other staff involved in teaching the course must be on-board, adequately briefed as to what is trying to be achieved and trained in use of the hardware and software.
- Finding questions can be difficult. Finding or devising 'really good' questions can be very difficult, but examples are out there.
- Consideration of how many questions to use, where to place them and what modes of use to employ is important.

During the lectures

- The role of the first lecture is crucial: be clear about the ways in which you will use the system and what you expect of the students.
- Do have a 'plan B' in case things go wrong (they can!)
- Do have a 'don't know'' option for responses to minimise guesswork.
- Be prepared to increase or decrease the thinking time allocated to particular questions. The noise level within a theatre is a good indication of collective progress!
- Be agile enough to adapt things; perhaps allowing some discussion between students of a question that has illustrated more than one misconception.
- Do devote enough time to the question episodes, particularly to discussing why incorrect answers are wrong.

After the lectures

- Do reflect. Consider re-using particular problem questions in revision sessions or assessments to reinforce concepts.
- Evaluate the usefulness of certain questions; if the class all got it correct, you might want to revise that question for a future instance of the course.

Conclusions

"We want our students to be trained for life as independent learners because we know that, in the real world, few people spend any time learning much by means of lectures."

Raine[35]

We have described the rationale behind and implementation of interactive engagement exercises in large class lectures, using an electronic voting system. This is an example of a 'disruptive technology' that challenges the role and utility of the traditional lecture in University education. It is a relatively widespread practice now and there are considerable resources available to help with matters of implementation and question design. We have found that wholly successful implementation is not always achieved in a course with no prior experience of this methodology and a pragmatic, incremental approach to its deployment is warranted, supplemented by staff reflection on the process.

The benefits to student learning and attitudes towards this are difficult to assess quantitatively. Yet there may be positive knock-on effects in terms of students' attendance at lectures (they are perceived as more useful, interesting), in student motivation and – particularly in the first year of study – the orientation to learning in a University context. The potential for change is encapsulated in the words of an anonymous first year student:

"I find I am even having to think in lectures"

Acknowledgements

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Outreach Activities: a summary for UK university science departments

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When asked what science subject they would take if it were not compulsory, 45% said they would take biology, 32% chemistry, 29% physics and 19% combined science - but 16% would not choose any of them.

Abstract
The dictionary definition refers to surpassing, outwitting or the act of 'reaching out'. The Funding Councils see it as "widening access and improving participation in higher education…… to equip people to operate productively within the global knowledge economy. It also offers social benefits, including better health, lower crime and a more tolerant and inclusive society".

Here in the Physical Sciences, whilst reaching out to widen access is an important part of our agenda, we see Outreach activities as primarily being targeted at improving the recruitment and retention of students. Many Physical Science departments are struggling to attract sufficient numbers of students and virtually all of us are also unhappy that the more able students are not choosing science for their higher and further education. This has led to the complete closure of a number of departments; a merger with cognate disciplines for some, or relegation to a 'service teaching' role for others. Since 1996, 28 universities have stopped offering chemistry degrees and almost a third of university physics departments have closed in the same period. Despite this dramatic fall in capacity, there is still a shortfall that is a major cause of concern for all but a handful of institutions.

There is a great deal of confusion within Universities as to how and why this situation has arisen and in this article I will attempt to collect and summarise items that have a direct bearing on these issues.

The first part will include the results of surveys into student preferences, public attitudes to science and scientists and lecturers' own opinions on the subject. The second part will summarise the recommendations from a number of sources who have given much thought to alleviating the situation and the final section will look at a selected number of institutions that are actively generating materials and methods that could be more widely adopted in order to improve the current climate.

Introduction
The dictionary definition of outreach refers to surpassing, outwitting or the act of 'reaching out'. The Funding Councils see it as "widening access and improving participation in higher education…… to equip people to operate productively within the global knowledge economy. It also offers social benefits, including better health, lower crime and a more tolerant and inclusive society".

Here in the Physical Sciences, whilst reaching out to widen access is an important part of our agenda, we see Outreach activities as primarily being targeted at improving the recruitment and retention of students and more recently, playing a key role in promoting 'strategic and vulnerable subjects' eg Physical Sciences, Engineering and Mathematics.

This paper summarises the published information both in print and on the web which deal with the questions: 'Why are students turning away from the Physical Sciences' and 'How can we reverse this trend'. We also look at a selected number of initiatives that are actively generating materials and methods that might change the current situation.

Background
Chemistry departments are under pressure due to the recent drop in entrants. The numbers of pupils attempting Chemistry A-level has been declining since 1995, following a gradual and spasmodic increase in numbers from the 1960s. The recent absolute decline also reflects a greater relative decline in terms of a percentage of all A-level entries and as a proportion of the relevant 16 to 19 year old cohort. Compared with 1991, the overall numbers of A-level entries in 2005 were 12.1% higher. But entries in

physics were 35.2% lower, entries in mathematics were 21.5% lower, and entries in chemistry were 12.6% lower. Since 1996, 28 universities have stopped offering chemistry degrees. Philip Kocienski, head of department at Leeds, says: “If the current trends continue, I estimate that there will be a maximum of 20 universities in the UK teaching and doing research in chemistry.”

Physics is similarly under threat. A survey of 432 schools and colleges in England and Wales revealed that although A-level entries in all subjects have risen by 14.6% since 1990, the number of physics entries had fallen by 38%. Nearly 10% of state schools with sixth forms now do not offer A-level physics, and of those that do 39.5% had five students or fewer taking it this year. Almost a third of university departments offering physics have closed in the past decade.

In a recent Institute of Physics report Lord May said "The profound problems facing science at A-level extend well beyond physics. We have consistently highlighted the general downward trend of students studying the sciences and if we fail to address this then we risk losing the ability to train the next generation of scientists, technologists and engineers".

There is a great deal of confusion within Universities as to how and why this situation has arisen. Those of us who work in the Physical Sciences often assume that the unpopularity of our subjects is related to public attitudes of fear, distrust and poor subject image. Furthermore, we have the feeling that our disciplines are ‘hard’ whilst all others are ‘soft’ and this deters potential applicants. Add to this the commonly-held view that science teachers are poorly qualified and motivated and that careers teachers do not understand the sciences and you have the recipe for a substantial self-inflicted inferiority complex. The fact that the majority of ‘famous’ personalities – presenters, entertainers and celebrities, plus the opinion formers – politicians, journalists and writers, have no scientific grounding and are often openly antipathetic or derisive of scientific matters, simply compounds the issue.

Surveys of Opinion
It is often thought that we do not know what influences students in their choice of post-school studies and future employment. Whilst it may be that large-scale in-depth studies are thin on the ground, there is plenty of evidence pointing to the basic problems.

Physics Students
A survey of the attitudes of Physics students can be found in ‘Getting Started in Pedagogical Research in the Physical Sciences’, by Norman Reid (see Table 1).

One question explored what were the likely factors which attracted the students into physics as a degree course. This question was given to 218 level 1 and level 2 students taking courses in physics and asked them to look back:
Which factor(s) influenced your choice of planned honours subject(s)?

There is no need to do more statistics on this. The pattern immediately tells us that, if we wish to attract more students into physics, then we can safely ignore most of the factors. *It tells us that the school experience is by far the dominant factor*. The quality of the school syllabus and the quality of the teachers are the critical factors. It is unlikely that we can influence the school physics curriculum although we might be able encourage able students to consider school teaching.

87% Enjoyment of subject	3% Friends
74% Good grades at school in subject	49% Likely career opportunities
27% Your teacher at school	9% Demonstrations, exhibitions, festivals
9% Your parents	7% Any other factors (please list below)
4% Information from mass media	....

Table 1: Factors influencing choice of planned honours subject(s)

However, any efforts in arranging special events, demonstrations, science centres, and exhibitions are likely to have only marginal effects in attracting students towards physics and are unlikely to justify the effort, energy and expenditure. There is one area which is open to us - *the perception of career opportunities*. Other research in the same survey confirmed that this is an area where more information is needed by school pupils and students.

GCSE Pupils
A recent online survey by the OCR (Oxford, Cambridge and RSA {Royal Society of Arts}) examination board involved 950 pupils from Years 9, 10 and 11, across a range of schools (both public and independent) and range of abilities, between November 2004 and February 2005. This revealed some interesting attitudes.

- Over 50% said that science lessons were boring, confusing or difficult.
- 25% of GCSE Science students say they won't be doing science after Year 11.
- The Human Body and Earth & Space are the most popular science subjects.
- 'Experiments in class' are the best thing about learning science followed by field trips and videos. 'Reading text books' or 'researching on the internet', are seen as some of the least effective methods, nominated by just 20%.
- 77% of pupils believe that the science they learn in school will be useful to them in the future. However, Year 11 pupils are twice as likely (30%) as Year 9 pupils (16%) to say it will be 'not very useful/of no use' implying that the level of relevance diminishes as the subject's complexity grows.
- 92% say curing diseases is the most important priority for science.
- Astronaut tops the list of 'most interesting scientific professions'.

- When asked to name a famous scientist, most students named Albert Einstein or Isaac Newton. With role models from centuries ago it's perhaps not surprising that when asked to describe a scientist the words 'boring', 'eccentric' and even 'dim' emerged. Just 7% described scientists as 'cool' and only 6% 'fun'. On the plus side, 79% of pupils associated scientists with being clever (although perhaps to be clever is not cool).
- When asked what science subject they would take if it were not compulsory, 45% said they would take biology, 32% chemistry, 29% physics and 19% combined science - but 16% would not choose any of them.

Popular Opinion
Physical Scientists often assume that the unpopularity of our subjects is related to public attitudes of fear, distrust and poor subject image. Admittedly there are problems associated with risk assessment and images of pollution but the products of science are widely respected and valued. Science is seen as important both by the public and the Government. However, many aspects are not presented or perceived as part of science. Examples of this are nanotechnology, which is perceived as engineering, and pharmaceuticals are not seen as products of chemistry and chemists. This means that the sciences do not benefit as much as they could from the respect given to their products.

A survey of adult public opinion in 2000 yielded the following major conclusions, which are often at variance with those held by school pupils.

- Three-quarters are 'amazed' by science.
- Two-thirds think it makes our lives better.
- Only 20% have no interest.
- 80% believe we should invest heavily.
- 70% approve of 'blue-sky' research.
- 43% think the benefits outweigh the disadvantages, 17% disagree.
- 43% think politicians support science 'for the good of the country', 25% disagree.
- 40% think the rate of progress is beyond government control but 30% disagree.
- 53% believe that politicians' decisions are swayed by the media with insufficient lead.
- 84% of people think scientists are valuable contributors and three-quarters think science is a good career choice.
- Two-thirds believe that scientists wish to improve our lives but the same proportion think we should listen more to ordinary people.

A similar survey was carried out in 2005 and revealed an *increase* in regard for science and scientists.

Chiral molecules	Diastereomers	Conformations	Projections
Carbonyl compounds	Aromatic substitution	Alkenes and alkynes	Alkyl halides
Introduction to spectroscopy	NMR spectroscopy	Atomic structure	Molecular energy storage
Descriptive trends in the Periodic Table	Numerical trends in the Periodic Table	VSEPR theory	Periodic Table database
Elementary radioactivity	Gaseous equilibrium thermodynamics	Chemical calculator	Molecule viewer
Glossary	Help with SI Units	Help with Algebraic manipulations	Help with Tables and graphs

Table 2: Chemistry Tutor contents list

Recommendations
Two thorough and substantial documents have been written with particular relevance to science recruitment.

Nick Jagger
Nick is a Research Fellow of the Institute for Employment Studies, with over 20 years of policy research experience. He particularly concentrates on scientific, engineering, ICT (Information and Communication Technologies), and managerial skills and their formation. He is also involved with international comparisons of high-level skills. Nick has examined regional, national and international labour markets, especially the labour markets for the highly qualified including scientists and technologists. These studies have used a wide range of approaches and methodologies.

Nick has a number of more general and wide-ranging ideas with particular emphasis on Chemistry, though most of his ideas are equally applicable to Physics. The paper contains a substantial collection of reviews of knowledge in this area. The following is based upon some of his suggestions arising from these surveys which are aimed more at policy making and policy makers rather than teachers.

Build on the positive attitudes to chemistry and its products
The benefits of the products of chemistry, such as pharmaceuticals, are widely accepted and acknowledged. There is a need to translate this into more positive attitudes towards chemistry and its study.

Reincorporate modern technologies into chemistry
Chemistry appears to spin off a sequence of new disciplines which are no longer identified with chemistry, such as nanotechnology, semiconductors, medicine, major aspects of gene manipulation, pharmacy, and forensic science and so on. This means that the public and potential students rarely understand the full scope of chemistry and its new developments.

Medicines

How medicines work
- Enzymes
- Receptors

History
Statistics
Drug synthesis
- Design strategies

Examples
- Antibacterials
- Analgesics
- Amphetamines
- Tranquilisers
- Antihistamines
- Hormones
- Hallucinogens

Homeopathics
Viagra, the Pill
Abuse

Semiconductors

Bonding in metals, insulators, and semiconductors
Impurities and Dopants
n-type and p-type
Zone refining
Chip fabrication
Nanotechnology

Cosmetics

History
Skin
- Aging
- Colouring
- Moisturisers
- Deodorants
- Sunlight

Hair
- Colouring
- Perming
- Combing

Perfume
Lipsticks
Toothpaste

Food

Vitamins
Minerals
Additives
Energy
- Dieting

Proteins
Carbohydrates
- Bread

Fats
- Prostaglandins
- Cholesterol
- Margarine
- Chocolate

Cooking
Smells
Drinks
- Caffeine
- Fruit Juices
- Alcohol
- Beer
- Wine
- Water

'Specialities'
- Natural Food
- Organic Food
- Junk Food

Chirality

Table 3: Contents of other Case Studies from the Chemistry Box

Pre-empt public misunderstanding of science and technology
Actively engage in a debate about safety and ethics associated with technology, perhaps by trying to refocus the debate around physics and chemistry rather than the technology.

Encourage science teachers to take-up and use appropriate careers materials
The changes in the Careers Service and the increasing need for science teachers to provide careers advice causes problems. Unfortunately these teachers often do not have up-to-date careers knowledge or use available materials. This suggests that there is a need for teachers to be encouraged to use appropriate material promoting science careers.

Understand the career and study aspirations of 16 to 19 year old students
It is surprising that it appears that the only study of the career and study aspirations of A-level students covered only Northern Ireland. If effective careers material and advice is going to be developed we need to know what resonates with 16 to 19 year olds.

Engage in the development of new curricula
It is known that science taught using up-to-date and everyday examples engage students better, and thus encourages take-up.

Encourage a dialogue between industry and teachers
It is known that industrial visits and industrial placements, if organised successfully, are very effective. However, work experience is often difficult to organise because of perceived health and safety problems.

Understand why science undergraduates choose science
There is a need to understand why science undergraduates choose to study science and why those who are otherwise qualified choose not to study it.

Urge universities to co-operatively respond to university funding changes
The climate of rapid and relatively dramatic decline in the number of entrants has resulted in some universities increasing their entry through bursaries and other measures. This can only lead to a more rapid decline of entrants at the other universities. This in turn could lead to the closure of more science departments - to the long-term detriment of the disciplines.

University lecturers should be aware of and engage in the debate surrounding 14-19 education changes
Curriculum changes undoubtedly have implications for the knowledge, skills and attitudes of entrants to chemistry courses in the future. Therefore, it is critical that those involved with university science engage with those developing any new curricula in a two-way dialogue.

Averil Macdonald
Averil is a well known education consultant, science communicator and author. She makes a number of valuable points on recruitment to individual departments and improving the perception of science among the general population. She has quite specific recommendations for encouraging more students to study science post-16 and points out that whereas some 300,000 students are eligible to go on to A-levels or Highers in the physical sciences each year, only around 40,000 - 50,000 choose to do so (the proportion in Scotland is 55% ; in England and Wales it is only 10%!). There is no doubt that the majority has already decided upon their post-16 subject direction by the age of 15 and projects targeting this age group may influence some to consider science-based careers who would otherwise be persuaded to choose non-science subjects post-16. Averil's comments are aimed squarely at the practitioner - the following is based upon her suggestions.

Produce resources
Teaching Resources which directly target elements of the 14 - 16 age range will be of great use to teachers if they introduce some cutting edge science that does not feature in text books and to which teachers may not have easy access.

ACTIVITY: Weaklings Revenge	ACTIVITY: A Knotty Problem	DEMO: A Mind reading act	QUIZ: Cable round the Earth
ACTIVITY: Hole in the Hand	ACTIVITY: Subtle Bomb Drop	QUIZ: Coin Pyramid	VIDEO CLIP: Tablecloth Pull
ACTIVITY: A Strange Plane - The Hoopster	ACTIVITY: Straw Flutes	ACTIVITY: Sound of the Sea	QUIZ: The Case of the Shiny Spoon
ACTIVITY: Hammer and ruler puzzle	ACTIVITY: Best Physics Experiment Ever - Microwave Oven	QUIZ: Hollywood Blockbuster Physics	FINALLY: Websites for simple builds and amateur science

Table 4: Amaze Your Mates Case Study from the Physics Box

Worksheets must be able to be photocopied, or easily downloaded from a website or a CDROM. They should fit onto an A4 sheet and must provide information as well as activities such as questions, quizzes, word searches, crosswords, comprehension exercises, data analysis (a great favourite with teachers!) etc. It is essential that the demand level is appropriate to the curriculum requirements and that the language level is not too high. Provision of answers for the teachers is always very much appreciated.

Websites should also provide information and associated activities such as those above. Students love interacting with websites but will not read vast amounts of text. Animations that illustrate a phenomenon are particularly good. Supplying the material on a CDROM allows the school to network the materials.

Videos or DVDs make a popular addition to a teacher's resources but must last for less than 30 minutes (preferably in short, say 5 minute, segments) as students' attention wanders. The topic must be directly related to the curriculum and ideally a topic for which other materials are not available eg manufacturing processes, nuclear power, sustainable energy, astronomy, medical physics or forensic science.

Careers Materials focusing on opportunities for those with science qualifications are often lacking in schools. Many 14 - 16 year olds are often advised about career possibilities by people who have no background in the sciences and therefore have little idea about the range of opportunities that science opens up to them.

Activities and Visits to Universities
Masterclasses, Lectures, Visits and Open Days are a good way to introduce 15 year old students to what university life is like. However if this is done on a departmental basis the number of students invited from any one school will need to be restricted and this will result in teachers sending the best students only and we end up preaching to the converted again.

General Open Days which can accommodate all a school's 15 year old students (perhaps 250) are much more effective but really have to be organised across the whole faculty, if not the whole university.

Activities and Lectures in School
Lectures should address the target audience and be of an appropriate level - some groups will be mixed ability and not all high flyers. They must also fit into the school timetable, lasting 45 minutes at most. The best lectures use a range of elements including images and practical demonstrations. Don't use a series of *PowerPoint* slides listing bullet point after bullet point as 15 year old students lose concentration far more quickly than conference delegates.

Activity days (or experience days), where students try out a range of 'experiments', have the benefit that they can accommodate all the members of a year group rather than just a few. There are two problems here – providing the materials and the time available. Schools will be reluctant to change the whole school timetable however good the event and other subject teachers will rarely release students to undertake a science activity when they are timetabled to do other studies. Ideally the activities should be able to accommodate a whole class (around 30) or multiples of 30 up to a half-year group (perhaps 150), which may be timetabled at the same time. Each repeat should fit into a school lesson - which varies from school to school but is most likely to be between 50 and 70 minutes.

Competitions are popular with universities but not as popular with teachers as they can rarely put in the additional time and money required to run the competition in school time and after-school activities are constrained by the need to get students onto school buses. Competitions will typically attract most entrants from the independent sector as they are less constrained by time and money. Some competitions have proved to be exceedingly popular (see below).

'Roulette Scam'	Mechanics and elastic/inelastic collisions	VIDEO CLIP: Dropping a hammer and feather on the Moon.	Coefficient of restitution for a cow pat!
Kinetic and potential energy gives *e* as function of initial and rebound heights	ACTIVITY: Measure bounces (and *e*) of different types of ball	APPLICATION: Show how LTA uses these simple techniques to assess tennis balls and ball-turf interactions.	THOUGHT EXPERIMENT: Perpetual Motion Machines – what if $e > 1$? Cartoon of perpetual motion machine.
DRAMATIC DEMONSTRATION: The pesky ping-pong ball!	Slides to explain mathematically the rebound phenomenon	Centre of Mass and motion in a gravitational field	Compute the time taken for a ball to drop to the floor from height, *h*
ACTIVITY: Measure your reaction time	QUIZ: Hanging in the air – footballers	IMPROBABLE RESEARCH: Flea Jumping	CHALLENGE: The Subtle Bomb Drop
QUIZ: The tumbling telescope	QUIZ: Fight flabbiness with physics	QUIZ: Flower power – fastest plant seed ejection	FINAL VIDEO CLIP: Stick motion beats gravity

Table 5: The Balls in Flight Case Study from the Physics Box

Resources
Outreach activities and the materials produced to support them bring benefits beyond the original institutions; fostering a general improvement in attitude to both the subject and HE. In several areas, the funding for activities is conditional on free dissemination to all appropriate institutions. We are in the process of collecting information on the availability of these items and this will be published on our website in the near future.

Two substantial collections of resources have been produced by the Centre.

The Chemistry Box
The Chemistry Box is written and published by the Centre and the resources may be downloaded from our website.

- Spreadsheets downloaded from government statistics covering the remuneration and employment of scientists. Presented via *PowerPoint*.
- Useful data for visiting speakers extracted from recent studies covering public attitudes to science and University admissions procedures.
- Practical resources such as structure-drawing software.
- A collection of 60 Chemistry experiments ranging in difficulty from those requiring little supervision to 'demonstration-only' versions.
- Games.
- Videos from the Liverpool University video library. These can be used as complete films or selected snippets may be pulled.
    - Salt, 30 mins.
    - Liquid Air, 55 mins.
    - Oxidation, 30 mins.
- E-learning modules covering particular areas of the school syllabus usually thought of as 'difficult' eg The Mole, Spectroscopy (IR, NMR, MS), Kinetics, Particles and Waves in Physics.
- *The Chemistry Tutor II* (Web-based)
- Case Studies (*PowerPoint*)

Waking without Chemistry

The backbone of the series is a light-hearted look at what a school pupil might encounter upon awakening and preparing for school should there be no such thing as a chemical industry. It contains lots of sound effects, videos and fancy transitions plus a little humour. It deals with topics such as semiconductors, electricity and lighting, polymers, electrochemistry, medicine, cosmetics, food, transport and clothing. The final part suggests a few topics that might assume importance in the future. Using this as a starting point, there are additional cases with the following contents:
- Semiconductors
- Cosmetics
- Food
- Medicine

The Physics Box
The Physics Box is written and published by the Centre and the resources may be downloaded from our website.

- Exemplar Case Studies (*Powerpoint* presentations) – around 20 are available:

Amaze Your Mates
This case study is simply a collection of off-beat puzzles and activities (see Table 4)

Balls in Flight (see Table 5)

Other *PowerPoint* presentations (see Table 6)

- Exemplar quiz/challenges on individual *Powerpoint* presentation slides to stimulate discussion – these are logical, mathematical and physics puzzles and activities.

Become an amateur scientist	Communication and Coding	Defying Gravity	Electrons in Motion
Kitchen Physics	Magnetism and Magnetic Devices	Natural Disasters	Natural Sounds
Our Natural Environment	Physics - a sideways view	Physics Tricks and Optical Illusions	Quest for Invisibility
Relativity & Reference Frames	Renewable Energy Resources	The Doppler Effect	The Radio Universe
Quiz Questions I	Quiz Questions II	Quiz Questions III	

Table 6: Other Case Studies from the Physics Box

- Lots of individual files containing suitable newspaper articles, short scientific texts, images, sound snippets, video clips, cartoons and background text relevant to GCSE level curricula.
- Lists of websites are given which are excellent resources for on-line teaching, books and also articles for further reading and descriptions of materials for demos/activities.
- Links to different careers: application of physical principles in everyday activities.

Activities
Most departments carry out some or all of the activities listed above: master classes, experiments at school, lecture programmes and so on. The following is a selection of national events that departments may subscribe to, or become associated with.

Chemistry Week
The RSC Chemistry Week is a themed week of events that is held every two years to promote a positive image of chemistry and increase the public understanding of the importance of chemical science in our everyday lives. As well as national events, activities are organised throughout the UK and the Republic of Ireland by RSC Local Sections.
The next Chemistry Week is due in 2007.

Lab in a Lorry
Lab in a Lorry is an interactive mobile physics laboratory staffed by volunteer practising scientists and engineers. The aim is to give young people aged 11-14 the opportunity to do experimental science in the way it actually happens; exploratory, accidental, informed by curiosity and intuition, but also bounded and guided by the experience and insight of practicing scientists. It is a joint initiative between the Institute of Physics and the Schlumberger Foundation and one of several Institute of Physics outreach programmes.

National Science Week
National Science Week aims to celebrate science and its importance to our lives, providing an opportunity for people of all ages across the UK to take part in science, engineering and technology activities. Hundreds of thousands of people across the UK take part in National Science Week activities every year.

The British Association coordinates National Science Week, providing a national context for each event.

Young Analyst Competition
Organised by the Analytical Division (AD) of the RSC, this encourages younger Analytical Chemists and involves them at all levels of AD activity. Last year this involved over 200 schools in regional heats and a national final.

Salters' Festival
The Salters' Festivals of Chemistry are an initiative of the Salters' Institute. Their objective is to help promote the appreciation of chemistry and related sciences among the young.

Salters' Festivals run from late March to mid June and provide the opportunity for enthusiastic young students to spend a day in a university department and to take part in practical chemistry activities.

CREST Awards
Celebrating **CRE**ativity in **S**cience and **T**echnology
BA CREST is a nationally recognised accreditation scheme for project work in the fields of science and technology. Aimed at students aged 11-19, the awards encourage students to develop their scientific curiosity, problem-solving and communication skills.

BRONZE 10 hours of project work Typically for ages 11-14	SILVER 40 hours of project work Typically for students aged 14-16 Links with industry encouraged
GOLD 100 hours of project work Typically for students aged 16+ Students linked with mentor from industry or higher education Can accredit Nuffield Bursary placements and Engineering Education Scheme (EES) project work	

Table 7: The Crest Award Levels

Through a mentoring system, the scheme facilitates links between schools and industry or higher education.

The awards are available in Science or Technology at three levels:

Students who have completed BA CREST project work have the opportunity to display their work at Regional Finals. Outstanding projects are selected for the prestigious national BA CREST Science Fair (http://www.the-ba.net/the-ba/ResourcesforLearning/BACRESTScienceFair/)

The Science Ambassadors Programme
The Department of Trade and Industry (DTI) funded Science and Engineering Ambassadors programme (http://www.setnet.org.uk/cgi-bin/wms.pl/181#TI) aims to promote STEM (science, technology, engineering & maths) by providing enthusiastic, vetted volunteers to work with young people and teachers in schools.

Science and Engineering Ambassadors can get involved in a whole range of activities and events, either organised and managed by the local SETPOINT or working with other organisations and schemes aimed at enthusing school-age children in STEM.

Examples of activities which are happening include:
- Ambassadors from large multinational companies linking with schools close to their sites and taking after-school engineering clubs
- Industrial volunteers working with classes on projects for GCSE Applied Science and Engineering
- Young IT professionals e-mentoring students in local schools

Aimhigher
Aimhigher is a national programme which aims to widen participation in higher education by raising the aspirations and developing the abilities of people from under-represented groups. Aimhigher partnerships build cross-sector relationships which break down the barriers which institutions and systems can unwittingly create for learners.
Funded activities include summer schools (http://www.hefce.ac.uk/widen/summsch/) to give school pupils a taste of university life, mentoring by students, and visits by staff from higher education providers to work-based training providers.

Funded projects relevant to the physical sciences are described in detail on the web pages of the RSC, IOP and SETNET and many of these have (or will have) resources available for download.

Young Engineers
Young Engineers' aim is to inspire young people to develop an interest in engineering, and, in doing so, recognise the importance and excitement of engineering as a future career. It develops and manages a national network of extracurricular engineering clubs in both the primary and secondary sectors and runs a number of engineering challenges and competitions. There is a great deal of overlap with the physical sciences.

Particle Physics and Astronomy Research Council (PPARC) Master Classes
These take place in almost every University and form part of PPARC's overall communications strategy, involving public engagement and public accountability.

The aim is to promote the understanding, appreciation and awareness of science areas so that young people's fascination for astronomy, space and particle physics is translated into an understanding and interest in all scientific areas, and a readiness to consider a scientific career.

CETLs
The HEFCE Centres for Excellence in Teaching and Learning (CETL) initiative has two main aims: to reward excellent teaching practice, and to further invest in that practice so that CETLs funding delivers substantial benefits to students, teachers and institutions. There are four centres that are of interest to us and they are intending to provide a great deal in the way of resources, courses, good practice and so on which will be made freely available to all. Their contact details are to be found in the references section

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E-Learning

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Abstract

E-learning as a term and its application in the support of learning has evolved considerably over the last ten or more years. This evolution comes from a noticeably different approach to learning by early adopters, as dictated by the technology of the time.

In order to bring the reader up to date with the role and use of e-learning and its associated technologies this article will review the meaning of e-learning as it evolved from little more than reading electronic books to today's concept of 'anytime anywhere' learning supported by the Web. It will attempt to clarify some of the confusing terminology surrounding e-learning and provide a basic introduction to some types of technology used to support learning. In addition some examples of the use of e-learning within the physical sciences will also be reviewed along with some pointers to current publications and national initiatives for up to date information about how e-learning is being used in higher education.

What is e-learning?

The rapid expansion in the development of computer technology in the 1980s and 1990s and the associated reduction in costs made it possible for computer supported teaching to enter mainstream education. However, many early educational resources were little more than electronic books. In 1989, the World Wide Web was invented by the physicist Tim Berners-Lee but it was not until about 1993-95 that it matured enough as a technology to be integrated into conventional education.

...it is important to use e-learning for specific educational purposes and not just because the technology exists. The best way to engage with e-learning is to consider how technology might support your teaching...

Thus from computer based instruction, where the student was sat at a computer working methodically through mostly linear content; this development in computer based resources suddenly opened up exciting new avenues for flexible, computer supported learning. With the now breath-taking developments of other computer technologies that link into the Web, the term e-learning has emerged to mean learning supported by computer technologies. This is different from traditional definitions such as ‘computer based training’ which was often little more than a bolt-on to traditional face-to-face teaching. E-learning made learning more interactive and could be tailored to suit different learning styles. Therefore, e-learning may be defined as ‘teaching and learning supported by technology and based on sound pedagogical practices’.

Terminology and definitions

It is an old adage that you don’t need to understand the workings of a car engine in order to drive: so it is also not important to understand much computer terminology to engage with e-learning. Indeed, an attendee at a recent workshop on e-learning commented: “[sic] Understanding that I had been using blended learning for years without knowing it!” Blended learning is a term that is becoming increasingly used in conjunction with e-learning and refers to the notion that you combine, or blend e-learning with face-to-face learning.

In order to try to put computer terminology into perspective, it is perhaps best to consider the important aspect of e-learning, which is the focus on ‘learning’. A teacher will use a variety of methods to support student learning so e-learning and all the technologies that go with it, can best be understood from this perspective.

A useful starting point is to consider what you want to do to support students through e-learning and then to consider the use of technology. For example, do you want to give students better access to electronic communication tools in order to promote group discussions? Once you know what you want to do you can find out what the associated technology is called and then how to use it. The next part of this article will review a number of new and developing technologies in an attempt to demystify much of the confusion surrounding their use, particularly for education.

Types of technologies available

Virtual Learning Environment (VLE)
VLEs encompass a range of utilities in one system to provide a learning experience in a virtual (online) setting. VLEs commonly provide a web interface to provide access to content and files to support student learning. They also provide a range of tools including email and discussion boards for communication. There are sometimes interactive tools such as 'live' communication tools and shared whiteboard tools for synchronous communication; and assessment tools which also provide students with results, feedback and other course information.

Simulations and animations
In many subject disciplines, not least the physical sciences, the use of simulations has great benefits for the visualisation and representation of concepts that can sometimes be difficult to explain. Laboratory simulations can also be of great benefit to students, allowing them to repeatedly run experiments that would otherwise not be possible in a real lab, due to time, cost, safety etc. One popular animation program called *Flash* is produced by Macromedia (bought by Adobe in Dec 2005). *Flash* allows authors to create interactive simulations relatively quickly. Other examples of the use of animations and simulations are provided in a 2006 workshop summary report from the Physical Sciences Centre entitled 'Producing Animations & Simulations' (see 'Further information and links' for details).

Video streaming
Video offers a number of educational benefits but downloading video clips can be slow. One way around this is to use video streaming, whereby the video starts to play as it downloads and continues to play as the next bit of the video is downloaded. This requires a dedicated video streaming server – a specialist computer server for delivering video which is a commonly used and readily available technology. Information, advice and examples of video streaming use can be found at the e-Learning Centre, a non-profit organisation based in Sheffield (see 'Further information and links' for details).

Podcasts
A podcast is the broadcast of video or audio across the internet. A podcast is different from a simple download of audio or video from the Internet, such as video streaming because these offer the media files only once and when the broadcaster chooses. Podcasting is a subscription service where the user downloads the files as and when they wish and is provided with automatic updates to the broadcast. This makes mobile access to media much more personalised. Podcasting is still relatively new but is starting to gain interest in education with a variety of resources being offered.

Although some may question the practicality of such offerings, some tutors are offering podcasts of their lectures. However, such podcasts certainly may offer benefits to disabled students or act as a useful revision aid.

Wikis
The term 'Wiki' has come into popular use in recent years perhaps largely because of media interest in its use. A wiki is essentially a type of website that allows the reader to edit, add or delete content (depending on restrictions) without permission from the website owner. One of the benefits of a wiki is that it can encourage collaborative writing, hence the media interest.

Blogs
The term 'blog' is a concatenation of the words web and log, an early description of people keeping online logs of discussions on various topics, hosted on web pages. A blog operates through the production of a blog website which requires a special blog server that enables posts to a blog to be categorised (by time, date, author etc). Individuals can often now get free hosting of their own blogs from host suppliers.

In education blogs are gaining interest, perhaps because students are used to using the technology for social purposes. To use a blog in an educational setting the teacher can create a blog outlining the content to be covered or discussed along with any associated links to resources. Students can interact with the blog, recording their thoughts and offering feedback; the blog ultimately develops into a resource in its own right.

Examples of e-learning in the physical sciences
A good starting point for finding examples of the physical sciences academic community actively engaging with e-learning is through the Physical Sciences Centre. Since they are in close contact with the academic community the Centre is aware of many of the good examples of the use of e-learning in chemistry, physics and astronomy. The Centre also runs national events to bring together practitioners of e-learning in order to share their experiences.

One such workshop run in 2003 in Cardiff (Using Virtual Learning Environments to Support Learning and Assessment) brought together speakers from around the UK to discuss their use of VLEs. Speakers discussed how they had developed and used a variety of resources to support student learning and discussed the various merits of VLEs. Another key aspect of the day was a review of computer assisted assessment (CAA) and how various speakers were using CAA to support their students.

A more recent event was run by the Centre in Edinburgh in 2006 (Flexible delivery and e-learning). Here speakers from institutions around the UK talked about their use of e-learning - testament to the expanding and widespread adoption of e-learning in the physical sciences. Speakers demonstrated how they had developed e-learning resources as part of specific modules for their courses (blended learning) but also for whole courses delivered entirely online. Further details and reports about both events and other information and links for e-learning can be found from the Centre's website, details of which are given below.

One example of a departmental approach to the integration of e-learning into the curriculum is that taken at the School of Physics in Edinburgh University. Simon Bates is a key member of staff there who has undertaken a lot of innovative work with e-learning and other related technologies, such as the use of electronic voting technology. Simon also offers sound advice through a set of principles for the successful adoption of e-learning, which are described in his talk that was given at the Edinburgh event and in the review in this journal.

At an international level, there are approximately 50 Physics Education Research (PER) centres located in universities and colleges across the USA. These actively engage with formal research into the development of e-learning to support physics teaching. One outlet for the results of their work is in the American Journal of Physics. As stated on the website at the University of Maryland's PER group: "The *Physics Education Research Section of the AJP* is intended for the presentation of research results on the scientific investigation of the learning and teaching of physics. This section is meant to serve both as an archival forum for the presentation and discussion of issues among physics education researchers and as a place for those interested in 'what works' in physics instruction."

Another example of the use of e-learning, this time to support chemistry teaching is the development of an online module produced at Manchester Metropolitan University. The focus of their work was "the promotion of active student participation within this online-learning module". The development of this work was supported through project funding from the Centre. A number of important considerations are listed such as adopting a structured approach to learning: using a variety of teaching and learning styles, eg online student workshops and overview lectures; and supervised independent learning sessions. The full report of this development project is available from the Centre's website under the 'Development Projects' section.

Research evidence supporting educational benefits of e-learning

Early adopters and evangelisers of e-learning were often viewed by many with caution: the perceived benefits of e-learning were often anecdotal or even outweighed by the disadvantages they produced. These drawbacks included problems such as a long development time to learn technical skills and a lack of evidence to suggest that e-learning had any real benefits for learning. This would exclude any placebo effect of students engaging with a different approach to teaching and learning practice. However, there has now been much more formal research undertaken to address the question of whether e-learning can offer educational benefits for academics and students alike.

Whilst there has been extensive general research on the benefits of e-learning there has also been discipline specific research relating to the physical sciences. Gorsky et al[1] have recently explored for the Open University in Israel how students adopt particular learning styles in a chemistry course with online support. Gorsky et al[2] also explored this with a distance physics course. Whilst not explicitly focused on e-learning it discusses how students interact at a distance - something key in an online (e-learning) community.

This is explored in more detail by Lyall[3] suggesting that a computer based learning programme could offer some benefits over print as long as they support the appropriate student learning style.

In another study on the effectiveness of e-learning Morgil et al[4] compared traditional and computer assisted learning approaches for teaching fundamental topics in chemistry. Students undertook pre and post tests after being exposed to 'computer-assisted teaching'. Students in the study showed a 52% increase in post test scores after being supported with computer-assisted teaching. This compared with only a 31% increase for the control group who did not experience the computer support. These results suggest that students engaging with computer assisted approaches benefited more than students who did not use computer supported learning.

Pol et al[5] discuss their research findings into how computer based instruction can help improve problem solving skills. They suggest that content from textbooks helps develop 'declarative and procedural knowledge' but not problem solving skills. By engaging students in a computer based resource on the topic of forces they found that students achieved higher results in problem solving than the control group who did not use the computer resource.

The research reviewed so far demonstrates two developments. The first is that the use of e-learning is becoming widespread and in some cases, mainstream in the teaching of physical science. The second development is that this research shows that physical scientists are not just accepting the benefits of e-learning at face value but are actively engaged in adopting e-learning based on tried and tested practice. This review will now consider a few examples of particular aspects of e-learning in use within the physical science curriculum.

Simulations

With the ever evolving capabilities of technology Barab et al[6] describe an early innovative use of Virtual Reality (VR) for an astronomy course. Students engage with VR technology to develop 3-D models of the solar system to help 'build rich understandings of various astronomical phenomena'. The work was undertaken as two case studies to evaluate a number of aspects of introducing technology into teaching, but a major outcome was that they found it effective in helping students engage with astronomy in undergraduate courses.

Another relatively early development of computer simulations to support student learning is documented by Littlejohn et al[7] with their development of an online chemical structure modelling tool. This web-based tool allows students to simulate the production and manipulation of chemical structures in a carbohydrate chemistry course. The benefits afforded include the ability for students to learn by 'trial and error' with adaptive feedback on their progress. One conclusion they draw is that technology has the potential to improve the *quality* of the learning experience.

Computer simulations are also the focus of a study by Jimoyiannis and Komis[8] to 'support powerful modelling environments involving physics concepts and processes'. This study explores the benefits of students' understanding of trajectory motion using software called *Interactive Physics* which simulates fundamental principles of Newtonian mechanics. Their results demonstrated yet again, that students who engaged with the technology achieved higher scores on tasks than the control group who did not engage with the simulations.

Discussing the use of animations and simulations from a chemistry perspective, Tasker and Dalton[9] consider how student misconceptions of a topic can arise from an inability to visualise structures and processes. However, these misconceptions may not be dispelled simply by showing them a visual model. These animations “can be compelling and effective learning resources, but they must be designed and presented with great care to encourage students to focus on the intended ‘key features’, and to avoid generating or reinforcing misconceptions”.
Based on this understanding Tasker and Dalton[9] discuss how informed by their research findings they developed the *VisChem* animations to demonstrate chemical reactions at a molecular level.

> *Thus from computer based instruction ...the term e-learning has emerged to mean learning supported by computer technologies ...and based on sound pedagogical practices*

Bruce Sinclair at St Andrews University has a collection of computer simulations for physics, which are freely available resources. This site is referenced below in the further information and links section. Another site, with other resources is the Physics Educational Technology website, again listed below.

Laboratory work
Although aimed at pre-university students, a study by Barton[10] explores the possibility of supporting teachers to innovate in physics teaching through the use of computer-aided practical work. This study explores the issues surrounding the development and integration of computer-aided practical work into the curriculum. This work raises an interesting point about a teacher wanting to attempt innovation on their own without support. It suggests that innovations can best be supported with a researcher more familiar with both the technology itself and the methods of teaching with the technology. This would provide valuable support for the teacher in becoming familiar enough with the process to be able to adopt it themselves.

Work by Burewicz and Miranowicz[11] looked at developing a strategy of using ‘computerised assistance for laboratory experiments’ by developing ‘pre-experimental, syn-experimental and post-experimental function[s]’. This was based on an experiment concerned with ‘empirical equations of reaction kinetics’. This research investigated the effectiveness of multimedia laboratory instruction on the outcomes of student practical skills. The authors found that the use of computerised laboratory multimedia instruction increased the student level of practical skills (more so than even the use of video instruction) and that fewer experimental errors were made. In addition, they found that students actually had to spend less time completing the experiment in the laboratory.

Another study that supports the work of Burewicz and Miranowicz[11] is by Waller and Foster[12] where they use the Web to develop a simulation of an experiment using a gas chromatograph-mass spectrometer. Students can use the online interactive equipment to simulate the experiment before actually going into the laboratory and using the real equipment. The authors found that this reduced the amount of in-lab tutorial time needed to familiarise the students with the equipment and enabled much more efficient use of their time whilst in the laboratory. Staff also reported that students were more confident using the equipment after having engaged with the virtual instrument.

Computer assisted assessment
Computer assisted assessment (CAA) has been around for many years and has often had positive reports, though the technical implementation of CAA is often fraught with difficulties. Potential gains made in helping the student learning process by adopting CAA are sometimes countered by the increased workload for the academic in having to become familiar with the technology. There are also potential administrative headaches when CAA does not provide for the automation of marking and feedback.

Ashton et al[13] explored any effect of CAA on students’ computing ability and performance in chemistry compared with paper based tests. The authors found that there was no medium term difference between CAA and paper based tests. In addition, with the re-wording of the questions for electronic delivery there was a risk that this might influence outcomes. This was also tested and no influence was found so Ashton concluded that CAA provided no difference from paper based tests.

These results can be viewed in two ways. The first is that CAA has no benefit over and above that of paper tests. Any possible time and other administrative savings by using CAA were not discussed so it is not possible from this study to determine if CAA can bring any administrative benefits. The other approach to these results is to suggest that if CAA is no less effective than paper tests then there is no reason not to adopt CAA. Additionally, if it can be shown that CAA can bring administrative benefits such as reduced time for marking and providing automated feedback then CAA has the potential to offer real benefits to both students and academics.

In another study on the effectiveness of CAA on student performance, Lowry[14] compared two groups of students and measured their results. Students using CAA could access the materials any time and two levels of feedback provided guidance to further learning. The results showed that students using CAA performed significantly better than the control group who did not use CAA, suggesting that CAA had a positive impact on student learning.

There is also a lot of international interest in exploring the effectiveness of CAA in the physical sciences. Diederen et al[15] from the Netherlands reported their work on the “Evaluation of computer-based learning material for food chemistry education”. This paper discusses the design requirements for digital exercises with respect to the users’ needs and found that the students found them useful and helped with their preparations for exams.

Keeping up to date with e-learning developments

There are a number of ways to keep up to date with the continual developments in e-learning use in the physical sciences. The JISC (Joint Information Systems Committee) funded by UK FE and HE funding bodies is one of a number of national initiatives and organisations that address e-learning. They regularly host events and conferences, and offer “strategic guidance, advice and opportunities to use ICT [Information and Communication Technologies] to support teaching, learning, research and administration”. Due to its technically oriented nature, the JISC undertakes much of its work in support of e-learning development and provision.

A number of Centres for Excellence in Teaching and Learning (CETLs) related to e-learning were funded in 2005. In particular, the Centre for Open Learning of Mathematics, Science, Computing and Technology (COLMSCT) has a focus on assessment and e-learning in the sciences.

There are a number of national and international organisations that promote the use of e-learning, but perhaps two UK organisations to note are the ALT (Association for Learning Technology) and the CAA (Computer Assisted Assessment) Conference. Both offer hugely popular conferences each year that bring together academics from a wide range of subject disciplines to present work on the use of e-learning within their own institutions. ALT is also a membership organisation with its own peer reviewed journal.

There are several journals which address e-learning research, some with a specific focus on the sciences. The *American Journal of Physics* has already been mentioned but there are also journals such as *Chemistry Education Research and Practice*, produced by the Royal Society of Chemistry and *Physics Education* by the Institute of Physics. Others include the *International Journal of Science Education* by Taylor and Francis, *Computers and Education* by Elsevier and *British Journal of Educational Technology* by Blackwell Publishing.

One other (freely) available service perhaps worth mentioning is Google scholar. This provides the opportunity to search across subjects for “peer-reviewed papers, theses, books, abstracts and articles, from academic publishers, professional societies, preprint repositories, universities and other scholarly organisations”.

Closing remarks

The integration of e-learning into the curriculum can be a daunting prospect. There are a plethora of technologies available and at first sight it might seem that a degree in computing is required just to understand it all. However, it is important to use e-learning for specific educational purposes and not just because the technology exists. The best way to engage with e-learning is to consider how technology might support your teaching, say by offering benefits through online communication or using computer simulations to explain a difficult concept. The next step is to simply trial it, but with a proper evaluation process in place to determine how well it worked for the intended purpose. This approach coupled with seeking the advice and help of colleagues who are already engaging with e-learning is a good way to start engaging with e-learning so that it offers real educational benefits for both you and your students.

Further information and links

Flexible delivery and e-learning workshop report, Edinburgh 21st Feb 2006
http://www.physsci.heacademy.ac.uk/Events/WorkshopReportsDetail.aspx?id=78 (accessed 18/04/06)

Using Virtual Learning Environments to support learning and assessment, Cardiff 19th Nov 2003 http://www.physsci.heacademy.ac.uk/Events/WorkshopReportsDetail.aspx?id=52
(accessed 18/04/06)

Producing Animations & Simulations, Hull 29th March 2006
http://www.physsci.heacademy.ac.uk/Events/WorkshopReportsDetail.aspx?id=81
(accessed 10/10/06)

e-Learning Centre
Streaming e-Learning/Webcasting
http://www.e-learningcentre.co.uk/eclipse/Resources/streaminglearning.htm
(accessed 10/10/06)

E-learning at Edinburgh
http://www.elearn.malts.ed.ac.uk/
(access 24/07/06)

Simulations in physics and astronomy
http://www.st-andrews.ac.uk/~bds2/ltsn/index.htm
(accessed 18/04/06)

Physics Educational Technology
http://phet.colorado.edu/web-pages/index.html
(accessed 10/10/06)

Flash
http://www.macromedia.com/software/flash/flashpro/
(accessed 18/04/06)

Centre for Open Learning of Mathematics Science, Computing and Technology
www.open.ac.uk/colmsct
(accessed 10/10/06)

The Association for Learning Technology
www.alt.ac.uk
(accessed 10/10/06)

International CAA Conference
http://www.caaconference.com
(accessed 10/10/06)

American Journal of Physics
http://scitation.aip.org/ajp/
(accessed 10/10/06)

Chemistry Education Research and Practice
http://www.rsc.org/Education/CERP/
(accessed 10/10/06)

Physics Education
http://www.iop.org/EJ/journal/PhysEd
(accessed 10/10/06)

International Journal of Science Education
http://www.tandf.co.uk/journals/tf/09500693.html
(accessed 10/10/06)

Computers and Education
http://www.elsevier.com/wps/find/journaldescription.cws_home/347/description
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Screen-Based Assessment

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A major driver for the adoption of screen-based assessment has been the increased intervention of Government and its agencies in promoting teaching, learning and, more specifically, e-learning

Abstract
Inexorably and across several fronts, screen-based assessment is becoming a major part of the experience of university students, particularly but not exclusively in the sciences. This movement reflects the emphasis the Qualifications and Curriculum Authority (QCA) is giving to the development of screen-based assessment at secondary level, where the universal availability of an e-assessment option in high stakes exams is an adopted goal[1].

The drivers for this change are economic, pedagogic and opportunistic. Rapid technological progress is facilitating the wider availability of computer based tasks that reflect authentically the learning outcomes of science courses. There is growing experience in the design of such tasks, with increasing commercial involvement, particularly in the USA. An examination of theories of assessment demonstrates that there are sound pedagogic reasons to pursue these developments.

The main focus of this review will be assessment for which a computer acts as a means of delivery, grading and feedback. I will outline the capabilities of contemporary systems, illustrate some good practice, and identify areas where the use of the technology is moving forward rapidly. There are exciting developments in the grading of free format responses, in diagram or text form, which are now emerging on a pilot basis. Of particular interest is the assessment of higher order cognitive and subject skills. Also important is the potential for item banks that can allow the sharing of the costs of authorship. Several of these issues are reviewed more fully in Conole and Warbuton[2].

Finally, I will comment briefly on assessment that is facilitated by computers without the computer acting as a grading tool. At a mundane level, this might involve the electronic submission of traditional assignments. Of more interest are electronically mediated peer assessment, the generation of e-portfolios, the grading of screen based experimentation and the evaluation of the student's performance in contributing to computer based group activities, eg Wikis, electronic conferences, etc.

Drivers for e-assessment?
E-assessment can offer increases in efficiency, though, clearly, the advantage that is realised depends on the scale of use of any assessment that is generated. Within the pedagogic model of the lone teacher and their class, efficiency gains are difficult to realise in all but the least complex assessments implemented under standard Virtual Learning Environments (VLEs). This explains the preponderance of basic 'progress check' quizzes, most of which are content based and used as a means of securing the engagement that is a prerequisite of learning[3,4].

There is limited rigorous data on the efficiency gains achieved by university e-assessment processes though it has been noted that the promise has not been translated quickly into practice[5]. A recent case-study based investigation has suggested that, in some prominent initiatives, pedagogical need has been the dominant driver for introduction of e-assessment[6].

It might be argued that e-assessment is a necessary part of a contemporary pedagogic strategy in that learning experiences that are increasingly mediated through screen activities should be assessed using similar media. However, the culture of regarding an *unseen* pen-and-paper exam as the 'gold standard' is still strong, in spite of the rapid advance of screen-based high-stakes assessment at secondary levels and in skills-testing by, for example, the UK Driving Standards Agency with its national network of testing venues.

Over the last few years, there has been a rapid growth in understanding of the formative role of e-assessment. The potential is evident when e-assessment capabilities are examined alongside criteria for assessment to produce learning, eg that devised by Gibbs and Simpson[3] using empirical and theoretical arguments. Key issues in their analysis are the regularity and quality of student engagement, the timeliness and quality of feedback and the student engagement with that feedback. Computer based assessment is completely flexible in its time of delivery and can produce high levels of engagement. The feedback from e-assessment systems is available instantly and can be differentiated with some sophistication (eg Rayne et al[7], Jordon et al[8]). Feedback loops can be closed by directing the student to further questions or other scheduled activities.

A major driver for the adoption of screen-based assessment has been the increased intervention of Government and its agencies in promoting teaching, learning and, more specifically, e-learning. This is evident in the targeted funds associated with the Fund for the Development of Teaching and Learning (FDTL) projects, the many Joint Information Systems Committee (JISC) initiatives and the Centres for Excellence in Teaching and Learning (CETL). Examples of activities generated via these funds are described below.

To an increasing extent, large publishers are becoming aware of an assessment market that is complementary to the conventional textbook sector. It has become commonplace to receive e-resources with the purchased book. Such resources might include an e-book, animations and simulations and end-of-chapter tests. This assessment element is expanding in volume and sophistication of construction. For example, John Wiley and Sons is now offering *Wiley PLUS*, a package that includes assignments that can be constructed from questions that are organised by chapter, level of difficulty, and source, and which include feedback . Students' responses are automatically graded, and the results recorded in a gradebook. With ~20 *Wiley PLUS* packages available in the Physical Sciences, including several standard texts, and compatibility with the market leading *Blackboard/WebCT* environment, it is likely that academics will find it attractive to adopt the embedded computer aided assessment, at least for non-summative purposes.

The summative role of screen based or e-assessment has been limited by many factors. There is the perception that machine generated tasks are too closed to represent authentically the full range of learning outcomes of a given programme. So, for example, one might test whether a student is able to recall the steps in a chemical synthesis or solve a problem in electromagnetism but might encounter more difficulty in assessing learning outcomes involving group work, communication or creativity. Anecdotally, this view has been challenged in a series of recent workshops in which academics were able to devise relevant though not always sufficient tasks for all the learning outcomes of an illustrative inter-disciplinary science course. Other anxieties concern; collusion, plagiarism, recognition of partial achievement, the logistical problems of engaging simultaneously an entire cohort, and, by no means least, institutional policies. Warburton[9] has analysed such obstacles within a framework for the introduction of computer aided assessment that contrasts a gradual low risk strategy, through quizzes and progress checks, with one that involves summative assessment and is high risk. He suggests that adoption of high risk strategies with consequent frequent failure has offered ammunition to those who oppose computer based assessment for cultural reasons.

Conservatism in the use of summative computer based assessment is not universal. From 2007, the Medical College Admission Test, which is a required part of any application to a medical school in the USA, will only be available online and will be administered via testing sites operated by Thomson Prometric. Illustrative questions are available via the Website (http://www.aamc.org/students/mcat/start.htm). The total test takes 5½ hours and includes sessions on both Physical and Biological Sciences. Most questions are simple in construction and require recall or interpretation. The advent of large commercial concerns offering 'total assessment solutions on a global scale' to professional bodies, Government agencies, universities and companies is an indicator of a trend which will undoubtedly affect universities.

Contemporary Systems

Systems that can be used by teachers to create a computer based assessment are now widely available. VLE systems such as *Blackboard/WebCT* and *Moodle* have limited intrinsic capabilities and, to date, the most developed computer assisted assessment (CAA) systems have been constructed using specialist packages, eg *Questionmark Perception*, *Tripartite Interactive Assessment Delivery System (*TRIADS), *Maple TA*, *SoftwareTeaching of Modular Physics (*SToMP), and *Open Mark*.

Questionmark Perception has been adapted widely (eg Ellis et al[10]). The company lists 21 question types that are supported by the software though many of these can be regarded as technical variants on the same fundamental task. For example there is no fundamental difference between a multiple choice question and one that is based on a drag and drop operation. A useful facility provide by the package is an interface that allows incorporation of *Java* or *Flash* elements. A relevant illustration of the use of this platform is provided by the Computer Aided Assessment in Chemistry project whose outputs are available online[11]. The demonstration of *Questionmark Perception* question types available via http://www.science.ulster.ac.uk/caa/index.html/ provides a useful introduction. Of particular interest are laboratory preparation questions that allow the student to construct a virtual experiment, thereby involving themselves in a learning task that transcends the superficial requirement for recall.

The *Tripartite Interactive Assessment Delivery System (*TRIADS) was originally developed via an FDTL project. It is now hosted by the Centre for Interactive Assessment Development (CIAD) at the University of Derby. It too provides for author flexibility through multiple question types, feedback facilities etc. The *Online Assessment and Feedback (*OLAAF) project[12] has provided a powerful example of the application of the TRIADS system. The tactic employed by the OLAAF authors has been to develop 'relatively few test items (not large item banks!) to detect critical misconceptions that may impede learning.' Feedback, crafted with equal care is then used to prompt appropriate further learning. The tests developed to complement a first year Molecular Biology module show how computer based assessment can be devised to cover learning outcomes at all levels with task and feedback that facilitate learning.

The authors have succeeded in devising questions that involve the students in the construction of knowledge.

Maple TA, although aimed at mathematicians and based around the *Maple* mathematics engine, is of relevance to physical scientists. It has been exploited elegantly by Greenhow and colleagues[13] to provide mathematics questions that, through the use of variables in the authorship, can be instantiated with random (within physical limits) values to yield endlessly repeated variants and appropriate feedback[10].

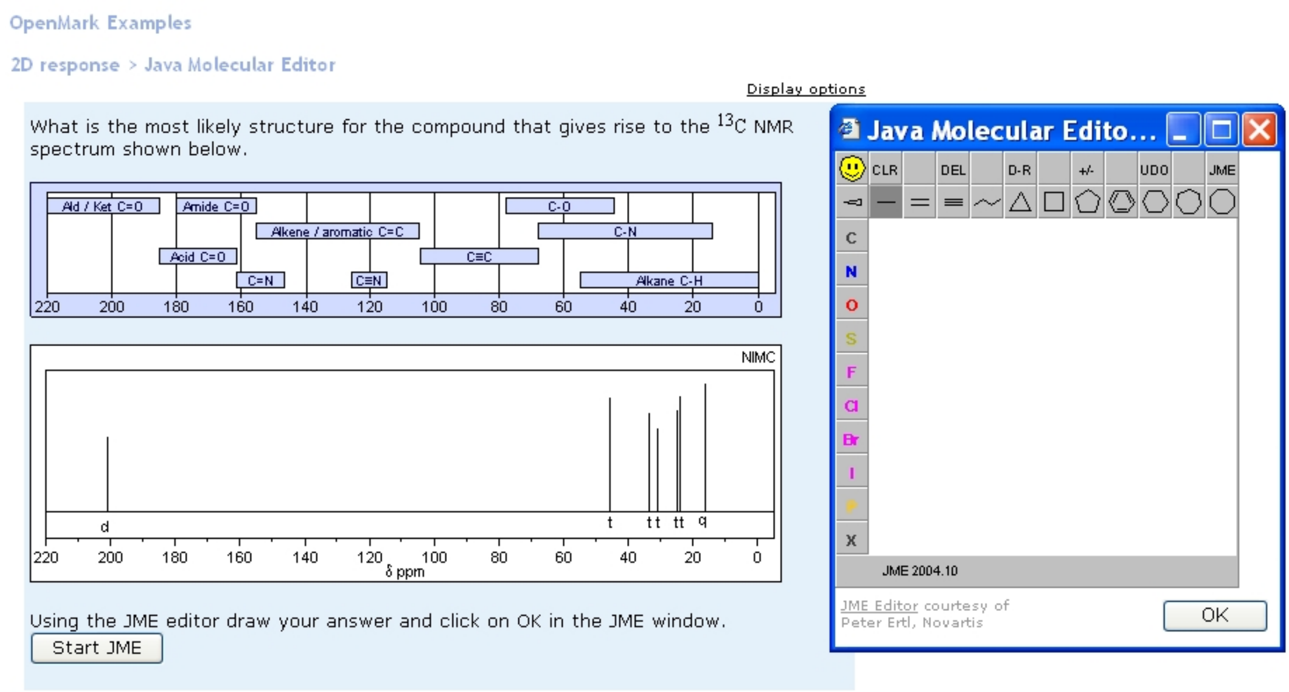

Figure 1: Java applets can provide additional (dynamic) functionality within assessment packages. In this example, a molecular editor is used to allow student construction of a response molecule.

OpenMark[14] is a system developed by the Open University that is used for both formative and summative online assessment. An online demonstration site http://www.open.ac.uk/openmarkexamples shows *OpenMark* supporting a range of responses;

- Text responses (eg simple text entry, chemical formulae, mathematical formulae and structured responses)
- Numeric responses (eg single entry, multiple entries, use of scientific notation, evaluation of significant figures and units)
- Multiple choice responses (eg including single choice, multiple choice, drag and drop, words within text, drag and drop words onto images, drag and drop images)
- 2d responses (eg placing a marker, drawing a line and the use of a *Java* molecular editor)

Most of these facilities are available in other systems. An exception is the use of a *Java Molecular Editor* (Figure 1), an open source tool devised by Novartis.

OpenMark allows three feedback stages and flexible grading plus, in common with the other systems, is a powerful pedagogic tool. A major constraint in its use is the complexity of authorship. In this case, XML code is required and, although based around templates, the most practical mechanism for realisation is collaboration between an academic who has the subject expertise and a learning technologist/software engineer. This problem exists for all systems at both the pedagogic and technical levels. Warburton[9] has highlighted the problem. There is a tension between the need for technical and pedagogical design skills in the design of advanced computer aided assessment and the traditional academic ownership of teaching in UK Higher Education. This problem is less evident in the newer universities who tend to have greater central control over the teaching process.

Two ways of potentially overcoming the expertise problem are the use of authoring tools and item banks.

As well as the authoring tools available in commercial systems (eg *Questionmark Perception* includes ‘wizards’ for all of its question types), there has been a recent major attempt to provide a generic solution. The JISC-funded *Technologies for Online Interoperable Assessment* (TOIA) initiative aimed to ‘remove many of the barriers for teachers who wish to move into computer-assisted assessment - and avoid lock-in to a particular proprietary system.’ Although not widely adopted, its use of Web based templates that are structured so as to provide the information necessary to work within the interoperability framework provided by the IMS Question and Test Interoperability (QTI) specification may provide a route that wins eventual acceptance.

The QTI specification provides a well developed and comprehensive mechanism for interoperability of computer based assessment systems. It includes a large range of question types, and specifies the metadata required for the questions to be incorporated within assignments and for reporting of results. Although several systems claim QTI compliance, the capability is fragile in most cases and import of questions from a different package may not be a practical option for the non-technical user. It is not clear whether QTI compliance will increase as the advantage of compliance is of limited value to vendors.

There are now several item banks available in the UK in the physical sciences. The largest and most accessible resource is provided by commercial text book publishers. The FDTL initiative has spawned a number of contributions although few with core relevance within the physical sciences. One of the most fully developed is the *Electrical and Electronic Engineering Assessment Network (*E3AN) which developed a database of nearly 1400 peer reviewed questions involving knowledge, comprehension, application and analysis.

The Higher Education Academy Subject Centre for the Physical Sciences is a gateway to several collections created through development projects[11,15]. These are implemented on a variety of platforms and are mainly in Chemistry. Direct contact with the author(s) may facilitate their use. Recent initiatives are increasing the breadth of coverage and a QTI compliant question bank is now under construction.

The interoperability issues that hinder use of question banks may be finessed by their availability as a Web service. In this case, the interoperability issue is addressed through standard mechanisms, eg use of XML. This technique underlies the commercial assessment packages that are widely used in the USA. A leading example of such a system is the *Mastering* Physics ‘homework and tutorial’ package (Figure 2) marketed by Pearson Education. This subscription funded Web resource includes learning materials, assessment and grading. In effect it functions as a discipline specific VLE. The company claim to have graded and provided feedback on 50 million student submissions of *Mastering Physics* assignments to date. All that is needed to access the service is a Web browser and a credit card!

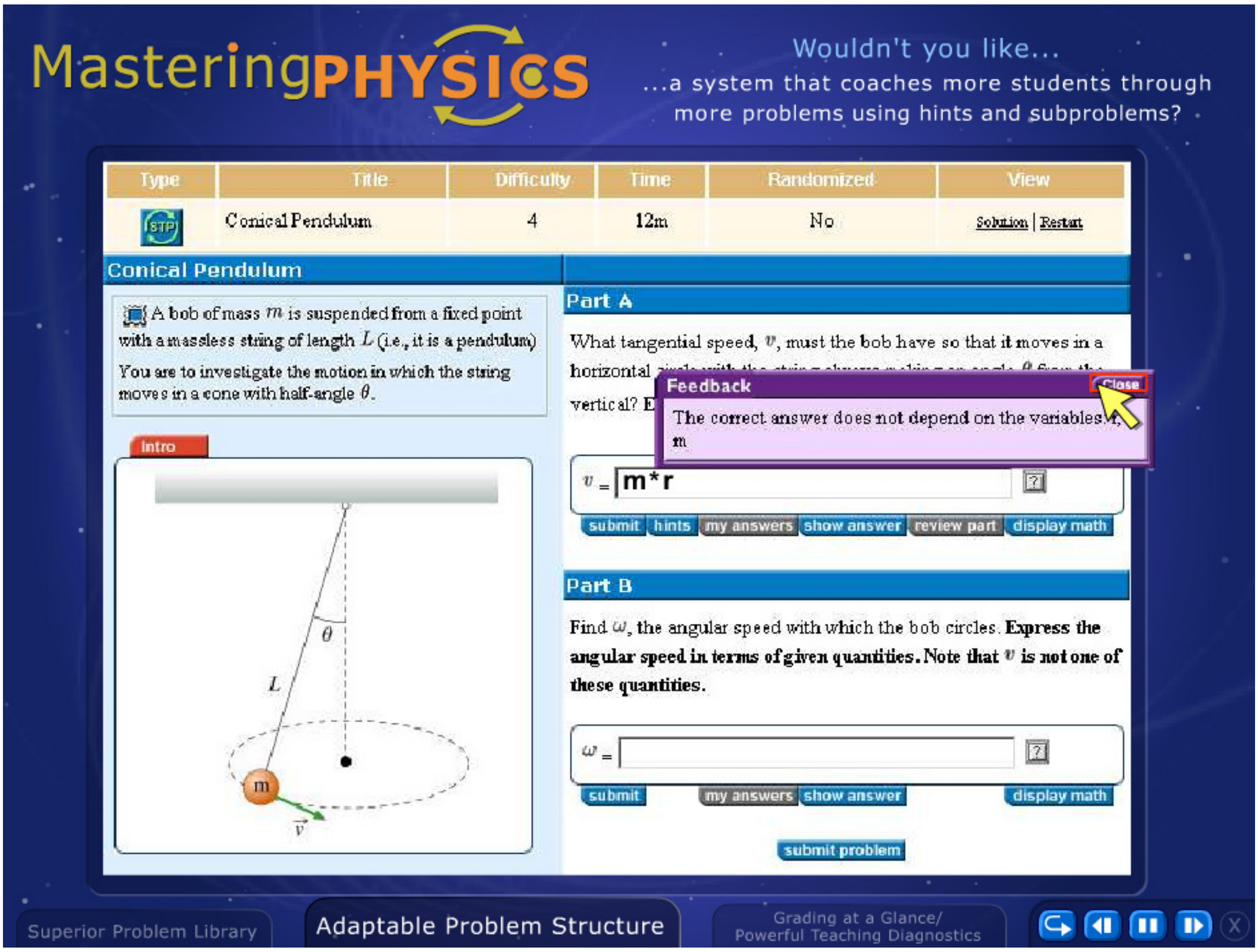

Figure 2: A screenshot from Mastering Physics.

A crucial issue in determining the viability of such Web services is the expectation of the customers. In the USA, students pay to access the systems determined by their teachers. Whether this expectation is exportable to a UK society which has enjoyed free higher education until recently is unclear.

Future developments

To date, virtually all computer based assessment has involved tasks with heavily circumscribed input mechanisms, eg ticking of boxes, dragging and dropping objects, manipulating graphs, entering words, numbers, expressions or equations, etc. There is a stark contrast between such activities and the writing of an extended essay or report. Given that there is a strong belief that such open response formats are needed to assess higher order learning outcomes, and the demands of marking and providing feedback on essays is so high, it is reasonable to ask whether computers can offer accurate simulations of the human teacher. Perhaps surprisingly, some progress has been made[16,17]. These studies are limited to short free text answers, eg up to five lines, and use variants on an information extraction technique based on the construction of answer templates generated by experts. Mitchell et al[18] have achieved impressive results in a medical student progress check that uses a database of 270 (very) short answer questions. After a period of intensive development the rate of disagreement between an expert moderator and the computer based system was reduced to 0.6%, which compares favourably with the ~5% disagreement between human markers in comparable studies.

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Marking of longer texts is less developed though there are well established tools for automatic feedback on writing style: content, grammar, usage, style, organisation etc. (eg ETS[19]). Such systems tend to rely on a databank of expert-marked assignments with which submitted assignments can be compared. Further work in this area and in the complementary problem of marking free diagrams is ongoing and progress may be expected.

The above discussion has centred on assessment focused tasks. Although formative, the assessment function is at the core of the design of the experience. However, there is a growing wealth of computer based activities that are designed as constructivist learning experiences. Examples are; simulations and virtual practice environments, group e-working within conferences or in Wiki construction, e-portfolio generation, etc.

In each case, an integrated assessment strategy would allow the computer activity to serve as input to an automatic grading and feedback tool. Strategies for such approaches are only now beginning to emerge with an accent on monitoring the quantity and timing of activity rather than the quality of the contribution. So, for example, it is straightforward to monitor when a student is making an input to a discussion forum – it is less easy to identify the value of that contribution.

One pedagogic strategy that has attracted significant interest recently is peer assessment. This has the merit of engaging the student with the performance criteria and can engender a feeling of community responsibility. Several workers have demonstrated how such strategies might be facilitated by the user of computers (see for example Davies[20]).

The strongest message from this review must be the need for collaboration in developing screen based assessment. There is little evidence that the pedagogic skills needed to develop more sophisticated computer based assessment materials are common in universities and there is limited experience of the newer integrated assessment strategies. Given the many pressures on academics, it is unlikely that the skills base will expand quickly and successful development strategies are likely to involve pedagogists, subject experts and software engineers collaborating to produce resources that can be shared. Vendors have adopted such an approach and are now offering high quality learning and assessment resources.

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Computer aided assessment and feedback – can we enhance students' early experience at University?

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Abstract
This project, funded by LTSN Physical Sciences (Learning and Teaching Support Network - now superseded by the Higher Education Academy Physical Sciences Centre) and FAST (Formative Assessment in Science Teaching) was primarily concerned with the production and evaluation of computer assisted assessment (CAA) materials to support students in the first year of chemistry programmes. A number of short assessment packages, designed to offer students formative feedback, have been written and incorporated into WebCT. Questions were chosen to exemplify a range of styles and were made available to students over the University computer network. The most important aspect of the work was the feedback offered to students within the quizzes, which was written in conjunction with undergraduate students to ensure its usefulness.

The effectiveness of the approach was evaluated by asking students to complete a questionnaire and by targeted interviews. The vast majority of the cohort (> 80%) used the quizzes, most to gain formative feedback and some as a revision aid prior to end-of-unit examinations. This communication will summarise our findings and highlight some of the advantages and drawbacks in using electronic feedback.

Although there was a very significant set-up time involved as well as an on-going need for student support in using the packages, student reaction was positive and examination performance was enhanced over previous years. Although firm conclusions cannot be drawn from one year's data, these results together with the very positive reaction from the students encourage us to further develop the approach.

Our aim was to use ICT to enhance student learning by adding to our traditional teaching methods, not by replacing them.

Background and context
Providing feedback to students on their work is vitally important if they are to succeed in their studies and particularly if they are to become independent learners. However, it can be extremely time consuming and demanding on staff to continually provide useful, individual feedback to students. Using electronic delivery has been suggested as having considerable potential in this area for enhancing student learning. This paper[1] describes some work carried out in 2004 to design, implement and evaluate a virtual learning environment (VLE) based system for delivering formative feedback to first year students.

At Bath, a number of colleagues had some limited experience with using electronic question banks, of which there are many published examples, and electronic assessment packages such as *QuestionMark Perception* for both formative and summative assessments. However, we had not been able to take a coordinated approach and were concerned that some students were not fully engaging with our programme of workshops and tutorials and so were not receiving useful formative feedback until end-of-semester examinations. By this time it was often too late to fill gaps in knowledge or to correct misunderstandings since the teaching programme (which builds on this work) moves on at an increased pace. We were anxious to overcome this while trying not to 'spoon-feed' students; we wanted to develop a method that would enhance feedback and encourage them to take responsibility for their own learning during the early stages of their university careers.

The University was trialling the use of a VLE (in our case *WebCT*) and so we were keen to investigate whether this could help us. All first year students (apart from those at home – none in this cohort) live in University accommodation that has network connectivity which allows ready access to computer aided learning (CAL) materials to students who have a computer. The University also has a Learning Centre with > 450 networked PCs which is open 24 hr a day. It therefore seemed to us that CAA would potentially allow ready access to feedback.

We were fortunate enough to obtain funding from LTSN Physical Sciences (now part of the Higher Education Academy Subject Centre Network) for a development project and for a case study as part of the FAST (Formative Assessment in Science Teaching) project[2]. The latter, discussed elsewhere in this journal, aims to develop successful approaches to formative assessment which enhance student learning. To quote from their project rationale[2]:
"There is an urgent need to develop new and effective approaches to formative assessment which are cost-effective and which:
- Capture students' time and attention
- Generate appropriate kinds of learning activity
- Provide regular and timely feedback which has an impact on student learning"

The model adopted was to design and to implement, using a VLE, a series of self-assessment quizzes which students could try outside the formal teaching programme. A bank of questions would be developed covering a range of topics commonly found in first-year chemistry courses. In addition, a small number of work packages were to be written so that, in case of difficulty, students would have access to revision exercises. For example, if students consistently provided wrong answers to questions, they could work through a short, focused presentation on a topic (eg Valence Shell Electron Pair Repulsion - VSEPR) to remind them of the basic principles and then attempt some further assessment questions. The final, and most important, stage of the project was to evaluate in detail the effects (if any) that using the assessments had on student performance.

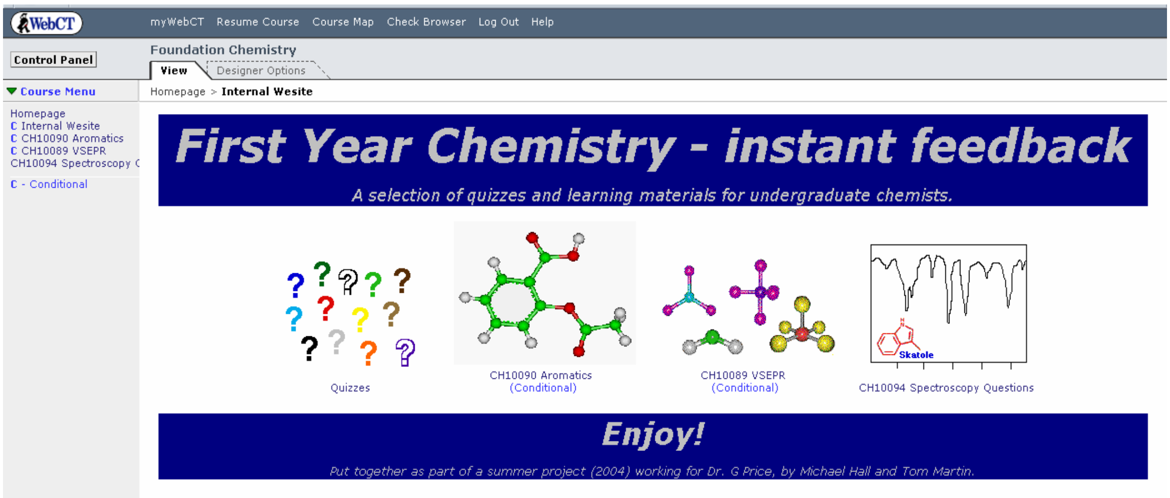

Figure 1: Start-up screen for the quizzes

We took this as a framework on which to base our work.

The target audience was our Year 1, Semester 1 units in Chemistry covering a mix of Inorganic, Organic and Physical chemistry, ie the first units studied on arrival at University for BSc and MChem programmes in Chemistry or Natural Sciences. The student cohort consists mainly of school leavers with A-level qualifications although there are a number with International Baccalaureate qualifications together with a small number progressing from Foundation courses or from a GNVQ route. Chemistry teaching at Bath is based around a traditional lecture format (ca. 6 per week) supplemented by problem classes (2 per week) and small-group tutorials (1 per week) with 5 – 6 students. Prior to this project, most formative feedback was delivered during tutorial sessions.

The outcomes of the work were designed to be:
- a bank of questions suitable to provide formative assessment and feedback to students in the early stages of their chemistry course
- a number of revision and feedback packages
- an evaluation of the contribution made to students' initial learning experience

Methodology and Implementation
Gibbs and Simpson[3] have summarised a series of conditions which should be satisfied if students are to receive useful feedback on their work. Our project was defined to meet a number of these conditions. One is that: "Feedback is understandable to students, given their sophistication". In order to ensure that this was the case in our work, undergraduate students (between years 1and 2 of the MChem degree at Bath) were employed over Summer 2004 to develop the packages and advise on topics to be covered and on the level and language of the questions and feedback. This meant that all the questions and feedback would be at an appropriate level. It also meant that the topics chosen were those of concern to students and not simply those that academic staff 'felt' were difficult.

The front page from the *WebCT* package – dubbed by the students 'instant feedback' is shown in Figure 1. It provides access into the question banks ('Quizzes') and to three of the revision work packages that were written.

For each section (eg 2 – 5 lectures) of material covered in lectures, a short multiple choice quiz (mcq) was written and mounted into *WebCT*. The aim was to allow students to test their 'basic' understanding of the fundamentals of the material as well as to give them a chance to find out whether they could apply this knowledge. The questions were based on some previously used at Bath, on textbook sources and on openly available internet sources. The students also wrote additional questions where needed. The staff member(s) teaching the units 'vetted' the questions for their suitability.

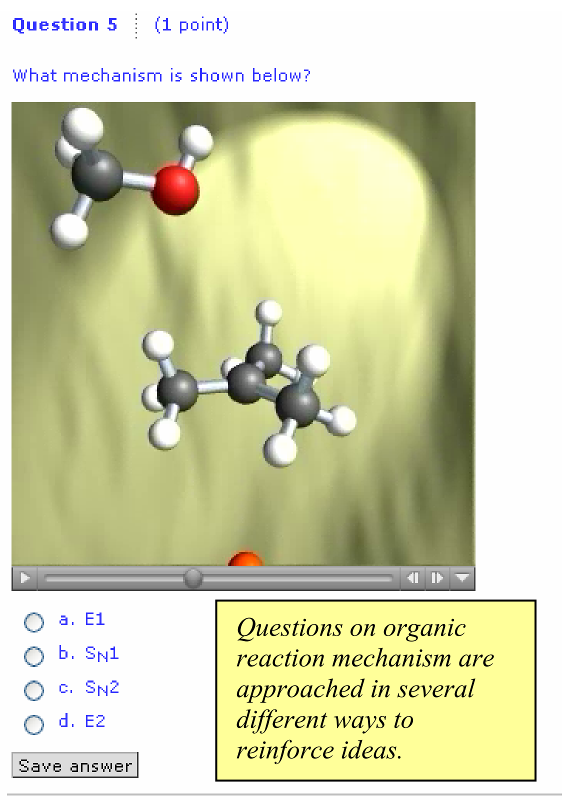

Figure 2: Example question type

Some 20+ quizzes containing 8-15 questions each were developed. Questions were chosen to exemplify a range of styles covering basic subject knowledge, the ability to use and apply concepts developed during the lectures as well as, where appropriate, background maths and physics. One advantage of using a computer over a paper based system is that some questions were designed around animations to enhance students' understanding of eg reaction mechanisms and reinforce ideas of 'where atoms go' during reactions.

The quizzes were made available via the VLE on the University computer network and students 'encouraged' to use it during their studies in order to monitor their progress; it was not compulsory. However, an added incentive was that most of the 'past paper questions' from the unseen examination comprising part of the summative assessment for the units were included in the quizzes.

Individual quizzes were released in the VLE as the material was covered in lectures. In this way, students were able to assess their understanding immediately rather than having to wait for tutorials. Timeliness of feedback is another of the conditions for effectiveness suggested by Gibbs and Simpson.

So far, this scheme could be implemented simply by assigning reading and problems from a textbook. What is the advantage of using a VLE?

The main advantage offered is that constructive, formative feedback could be built in and made instantly available to the student. At the most basic level, students could use the test scores as an indication of their progress. However, we were careful to stress that students should use the quizzes to help develop a more independent style of learning and not simply focus on obtaining marks.

Simply telling students whether they had answered questions correctly or not would be of limited value. Into each question was therefore built some constructive feedback – drafted by staff but vetted and approved by the undergraduate students so that it is at an appropriate level to the user. Even if the question was answered correctly, feedback was given to enhance the learning (eg "Well done – you obviously remembered the correct units for the gas constant, R"), to reinforce good habits and to provide reassurance for less confident students that they really do understand the material involved. Incorrect answers were met with hints as to where students might have gone wrong. (eg "Have you considered the units of the gas constant?", "Think about how many joules are in a kilojoule" or "What does the '1' in 'SN_1' mean?"). In this way, students were not simply fed the answer but forced to think about why they were not correct in the first attempt. In the event that they were completely unable to answer a question, students were directed to where they could get help. They were also encouraged to use the question as a basis for discussions during tutorials. Some of the question types are illustrated in Figures 2-4.

In an attempt to enhance the feedback given, some short 'revision packages' were written to be used when students needed further support on a topic. The principle that we tried to adopt follows the flow chart in Figure 5

This aspect of our work is at a very preliminary stage but represents an extension to how VLEs could be developed. In the main, students are currently directed to appropriate sections in lecturers' notes, text books or internet and other sources as appropriate. However, in one or two cases, we have prepared and incorporated short, highly focused revision packages which students can work through before returning to the self-assessment quiz.

Some technical problems encountered in incorporating material into *WebCT* meant that some clips could not be integrated with the quizzes as seamlessly as we had hoped. Nonetheless, student feedback was positive and it is hoped that further development of VLE interfaces as well as appropriate local implementation may allow much more effective use.

Evaluation of the project
The packages were used in Semester 1 and early stages of Semester 2 of 2004-2005. A full evaluation has been prepared[1] and will be summarised here.

An initial evaluation of whether our approach was effective comes from a comparison of the unit results and the number of students who withdrew from the course during Semester 1 compared with previous years. During the study, only 1 student withdrew from the course before the Easter vacation compared with 6 in the previous session.

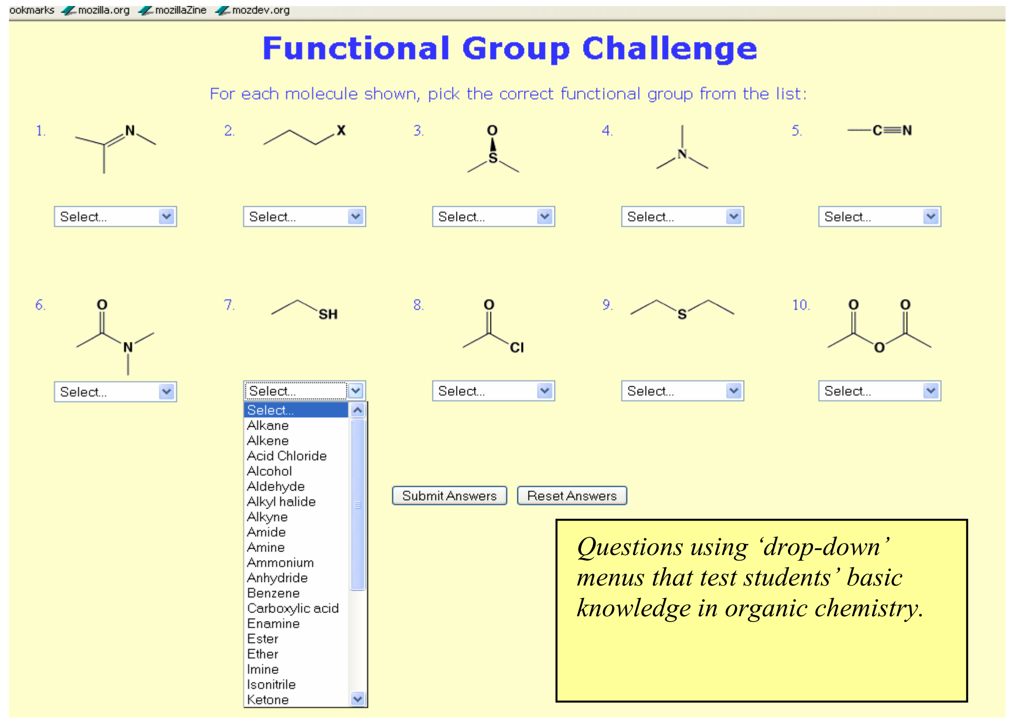

Figure 3: Example question type

In terms of the summative assessment of the unit, there was a distinct improvement in performance for this session. The assessment comprised a piece of problem-based coursework done mid-way through the semester together with a multiple choice question examination and a problem based examination held at the end of the semester.
The cohort showed a significant improvement over the previous year with the average mark moving from 56.7 (sd = 13.4) to 65.2 (sd=10.6). For each individual component, an improvement was shown with a pronounced (perhaps not unexpectedly) increase in the mcq examination where the average moved from 53.1 to 60.1.

Of course this is at best a crude evaluation of the effectiveness of our approach. Many other factors affect performance and withdrawal rates. The average A-level entry grades were a little higher for the later cohort and this may account for some of the improvement. Part of the increased performance may simply have come from students' increased familiarity with question styles. However, we can at least conclude that the introduction of enhanced feedback has not harmed summative performance.

The primary evaluation of the project involved asking students to fill in a questionnaire together with some targeted interviews. The questionnaire was circulated after students had received their Semester 1 results, allowing time for students to reflect on their use of the quizzes.

From a cohort of 115 students, 98 returned questionnaires, a response rate of 85%. Of those who returned questionnaires, we were pleased to see that over 80% had used to the system to at least some extent. Given the well known cynicism of some students (the "it doesn't count so I won't bother" syndrome) this was satisfying.

The students who *did not* use the packages gave a number of reasons ranging from "Didn't have the time, kept forgetting." and "Didn't think it would be worthwhile" to those who tried but had technical problems. This is well illustrated by a comment "Attempted to use them but became frustrated with system's inability to handle 99% correct answers. eg 99kJmol^{-1} was right but 99 (space)kJmol^{-1} was wrong". The latter comment clearly has implications for question design although it seems that this student was focusing more on getting the mark than acknowledging that they had obtained the right answer as an aid to learning! There were some interesting comments in terms of pedagogic factors including "I don't find computer learning particularly useful. I tend to remember things by rote if I use quizzes, instead of learning and understanding"; "Preferred to revise using books and notes with past papers, rather than using the computer, I don't really feel that MCQs are my favourite way to learn, I often feel extremely unmotivated to do them"; "I did not feel that the quizzes would help me, as they are not the style of revision that I know helps me the most" and "I would rather learn using a pen and paper!".

Given that current students are highly computer literate and, we are sometimes told, regard traditional teaching as old-fashioned, We were surprised at these comments, albeit that they were small in number. The responses were anonymised so that it is not possible to correlate use of the system with final assessment marks.

Of the 80 students who *did* use the system, 65% used them for formative feedback during the semester, the others using them simply as a revision tool in the run up to examinations. Of the former group, about half used all the quizzes and of the rest, the preference was to use the quizzes for units that were found difficult rather than those in which the students were most interested. The majority of students felt that using the quizzes had helped them to learn the material covered in the units. While anecdotal in nature this, along with the improvement in examination performance, suggests that this was true.

- All students would use it after each lecture segment
- Tutorials could be better focused on student needs, improving their learning
- Fewer visits to staff with trivial problems would be needed leading to more effective use of staff time in dealing with problems

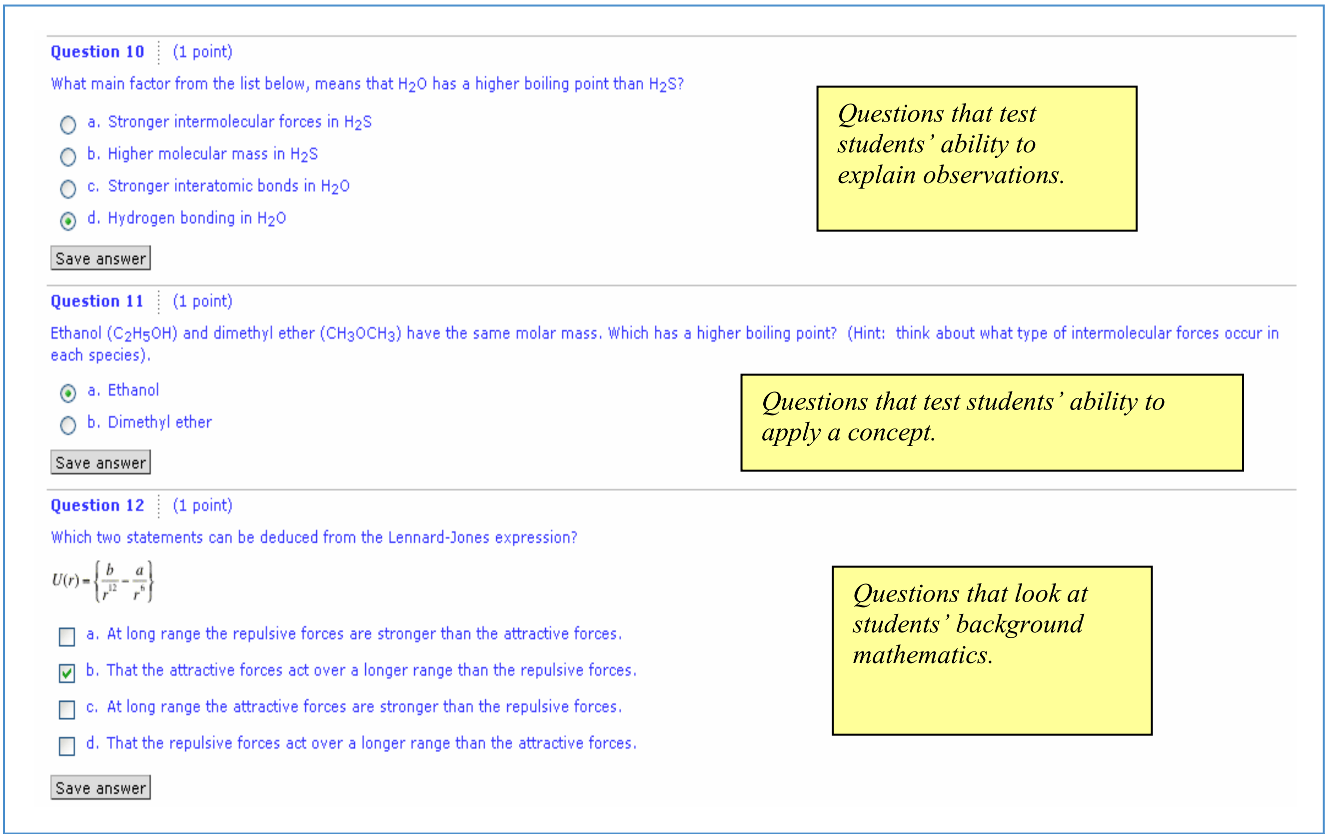

Figure 4: Example question type

Students though were neutral on whether the feedback had helped them to actually plan their study or whether use of the system helped in bridging the school-university transition.

There was a slight preference for the suggestion that using the packages helped to develop independent learning, although few students seemed to have used the feedback as a basis for seeking further help during tutorials. Only 10 students felt that the CAA approach was better than the traditional tutorials, even though it is more readily available. A larger proportion of the class used the feedback quizzes as an aid to revision for the final assessments. Of these 80 students, all but 9 used the quizzes to gauge how their revision was proceeding and the majority used them as a diagnostic tool to focus their revision and agreed that the feedback was helpful in learning the material. The ability to get answers at any time was, not surprisingly, regarded as an attractive feature. Again perhaps not surprisingly, students expressed strong preference for visiting tutors to get problems answered rather than simply using electronic means.

Discussion and comments on good practice
Overall, we were pleased with the student acceptance of the work and the apparent success of the project. When we designed the package, our hope was that:

- More effective revision with less need to visit staff during revision time
- Better performance in assessments
- Higher student satisfaction with Semester 1 studies.

So, what was the result? A high proportion of the students used the system to get formative feedback during the semester while a smaller group used it as a revision aid. Most students felt that using the quizzes had improved their overall performance and this is supported by the change in average marks, albeit for a single cohort.

The main unforeseen circumstance that we encountered was the comparative overloading of students in the first few weeks of their university careers. Although we had hoped that our feedback system would help in the school-university transition, it was hardly used in the first few weeks. Enquiries to students showed that many were overwhelmed by the number of new procedures, tasks, skills and general activities that take place in the first couple of weeks, both academically and socially. A second introductory session was held after 4-5 weeks of the semester and usage increased afterward.

We underestimated the time commitment required to set up such a package of quizzes, even when using a commercial software product such as *WebCT*. We were pleased at the comparative lack of technical problems faced by students – albeit that this was offset by the staff set-up time spent ensuring that things were robust.

The initial set-up time and technical support necessary for such a system should not be underestimated. Sourcing, devising and inputting the questions was time consuming (ca. 13 weeks for the summer students). Even though a commercial VLE was used, there were technical issues in its use in terms of student access, passwords etc.) and in working out how to include some question types (eg those with video clips or the interface with *Powerpoint*). Individual students also needed help with accessing and navigating the system so that some further support during the Semester was vital to the successful operation.

A number of technical issues cropped up during implementation of the VLE. Mainly, these are to do with local implementation but the major operational one concerns the way in which *WebCT* structures quizzes. The same problems were encountered when using *QuestionMark Perception* for similar purposes. Neither package is ideal for 'formative' assessments. In fact, the University of Bath recently made the decision to adopt *Moodle* as its VLE and so we are about to undertake the migration of the packages to this new system and this may overcome some of our problems.

Our aim was to use Information and Communication Technologies (ICT) to *enhance* student learning by *adding to* our traditional teaching methods, _not_ by replacing them. In this we seem to have been successful, at least in terms of student acceptability. One telling comment which applies to CAL methods in general rather than specifically to this project was *"*I came to Bath because of the friendliness and approachability of staff – and then you send me away to work with a computer on my own". Clearly, we need to manage the introduction of CAL carefully if detrimental changes to our departmental ethos are not to occur.

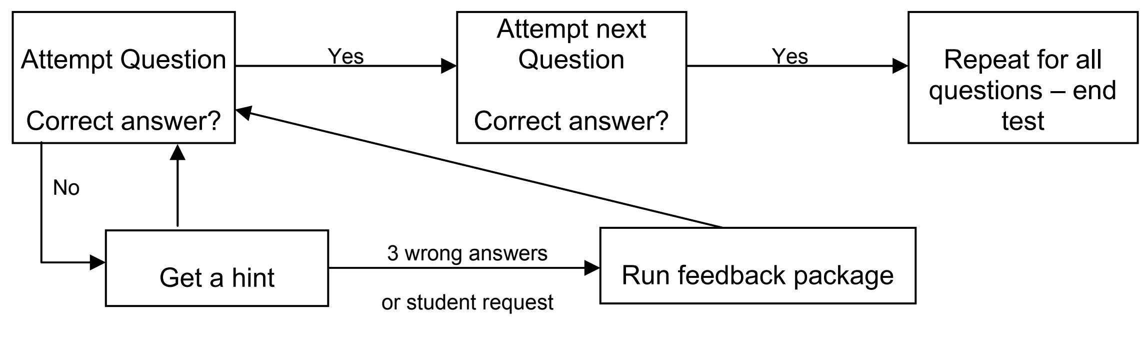

Figure 5: Flow chart for enhanced feedback

Conclusions

So, in terms of effective feedback, our system meets many of the criteria of Gibbs and Simpson. The packages are released in parallel with the lecture material so that it is relevant and gives students the opportunity to monitor their progress in time to seek assistance if necessary. The feedback given is 'instant' – available from a PC at any time. The quizzes were designed to cover both revision of background knowledge, basic understanding of new material and the ability to use and apply concepts so that a range of student skills was needed. The feedback given should have been at the appropriate level for students and we were continually careful to emphasise the diagnostic nature of the quizzes. The marks achieved were not important: the main aim was to allow students to monitor their progress and so help them to take responsibility for their own learning.

Acknowledgements

We are grateful to the FAST project and the LTSN (now Higher Education Academy Physical Sciences Centre) for funding some of this work. In particular, Evelyn Brown was our 'FAST mentor' and gave us valuable help, particularly in the evaluation of our approaches.

In writing this paper I need to thank Mike Hall and Tom Martin, two undergraduate students who worked on the project and contributed many ideas of their own from the student point of view. Also, the input of other staff at Bath who contribute to 1st year teaching is acknowledged.

Notes and references

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Using a VLE to enhance a Foundation Chemistry laboratory module

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Abstract
For the past few years, we have been experimenting with an e-learning approach to our introductory laboratory classes for first year students. Our overall objective was to maximise students' useful time in the laboratory. We considered that time spent with students gathered around a desk watching a demonstration is not an efficient use of staff or students' time.

It is well recognised that students' performance in the laboratory can be enhanced if they are familiar with the background of the experiments which will be conducted, hence the use of 'pre-labs'. We have been delivering our 'pre-labs' electronically by requiring students to work through a package before coming to the laboratory. As well as covering the theory and background to the experiment, short video clips have been included so that students will also have seen the experiment being performed. They should at least recognise the apparatus! The package concludes with a short assessment quiz which must be completed.

The packages were mounted on the University network using WebCT and meant that students could undertake the exercises at a time (and place) of their choosing rather than being confined to set laboratory hours.

This communication will describe the packages and our experiences as well as an initial evaluation of our approach. Although largely anecdotal, staff felt that they spent less time on more mundane aspects of laboratory work and more time discussing chemistry. Students also felt that they were better prepared for the experiments before they came to the laboratory. Some of the pitfalls and technical problems that had to be overcome will also be described.

We wanted to update our classes to use the technology available to make them more efficient and effective.

Background and context
One thing that all lecturers teaching Chemistry in Universities would surely agree on is that practical work is an essential element of our courses. The acquisition of laboratory based practical skills is an aim and requirement of all chemistry based programmes[1,2]. In addition, well designed practical work can stimulate students' interest, illustrate applications of concepts covered in lectures and enhance learning in other parts of their course. Unfortunately, the opposite can also be true; if experiments are repetitive and uninteresting or if students feel that they are 'following a recipe' in synthesising something or making measurements on a piece of apparatus, they can quickly become 'switched-off' and disillusioned. In addition, laboratories are expensive to operate and maintain and so it is important that they operate effectively.

As a department at Bath, we were fortunate in 2003 to move into a new, purpose built teaching building containing two laboratories, one each for 'synthetic' chemistry and 'physical' chemistry as well as a computational suite. The reorganisation necessitated by the move gave us the opportunity to reexamine our practical work, in particular that done by students in the early stages of their undergraduate Chemistry programme. At the same time, the University of Bath was piloting the use of *WebCT* and *Blackboard* as Virtual Learning Environments (VLEs) with which to support student learning. We decided therefore to experiment with using *WebCT* to underpin our Foundation Chemistry laboratory unit which is done by students in their first Semester at Bath.

This paper will describe our approach and experiences as well as an initial evaluation of running this new unit[3]. The module comprises a balanced programme of inorganic, organic and physical (including computational) chemistry although in view of the space limitations here, we will concentrate on the physical chemistry aspects for which the authors had main responsibility.

Motivation and design criteria

The reasons for performing laboratory work in Chemistry at undergraduate level have been extensively discussed[4-6]. The overall aim of this 'Foundation Laboratory' module which runs for the students' first semester in Chemistry at University is to introduce the students to a range of practical methods and related skills which they will use in more advanced practical units later in their course. While other forms of practical are used in other parts of this unit and developed further later in the course, the initial physical chemistry component is expository in nature[6,7]. It has been argued that little useful learning takes place in this form of practical work. However, we feel that it serves students well at this early stage of their course in terms of building confidence in performing practical work as well as to bring students to a common level of experience, independent of their pre-university studies. The detailed objectives of the physical chemistry aspects of the unit are:

- to reinforce aspects of the material taught in lecture units (at this stage mainly a revision and extension of pre-university work);
- to develop practical skills in assembling apparatus and accurately making, recording and reporting observations;
- to develop the ability to assess the quality and significance of measurements;
- to gain confidence in using PCs for calculating results and analysing data eg using spreadsheets.

Major emphasis is therefore placed on acquiring practical skills and analysing results. Inevitably in a unit taught early in the course, experiments may be scheduled before the background material has been covered in lectures. The experiments are therefore based on topics such as Hess's Law, pH changes and visible spectrophotometry (colorimetry) that are usually met in pre-university chemistry courses.

While our intake has expanded over recent years (by around 40% over the past 5 years), this was *not* the major driver for change and for the introduction of ICT (Information and Communication Technologies). We wanted to update our classes to use the technology available to make them more *efficient* and *effective*. Typically, classes of around 40-45 students are supervised by a member of academic staff with the assistance of two or three research student 'demonstrators'. Our overall objective was to maximise *useful* time for students in laboratory. In order to achieve this we wanted to:

- limit time that students spend waiting for routine demonstrations of eg setting up apparatus and/or waiting to talk with staff;
- eliminate students listening to class presentations that were unnecessary for them;
- allow staff to concentrate their time on students who need it most;
- speed up marking to enhance the feedback to students;
- encourage students to begin to take responsibility for their learning in the lab.

It is well recognised that students' performance in the laboratory can be enhanced if they are familiar with the background of the experiments which will be conducted. Most often, 'pre-lab' exercises are used to facilitate this[8,9]. For our classes, we had previously used a short, paper-based quiz to indicate the extent of knowledge needed for each experiment. The answers were discussed with a demonstrator before commencing practical work. The major enhancement offered by using the VLE was in this area of 'pre-labs'.

A major factor influencing our pedagogical approach is the variable level of practical experience with which students enter university. This depends on their school or college background and the type of pre-university course studied. Previously, many of our laboratory classes had started with a short introductory lecture and/or demonstration which students watched passively. This was often unnecessary for students with a good practical background while some others did not acquire the necessary information. We considered that time spent with students gathered around a desk watching a demonstration is not an efficient use of either staff or students' time. We therefore wanted to use the VLE to allow students to cover the necessary theory and background work at their own pace. In addition, there is ample evidence[10] that if students are expending effort on the mundane aspects of experiments such as constructing apparatus, they can perform the experiment badly and hence miss the most important aspects. We felt that some familiarity with the apparatus to be used before coming to the laboratory would therefore help most students so that this was built into the VLE package. An additional local factor which encouraged this approach is that the vast majority (> 95%) of our first-year students live in rooms in University residences, in all of which network connectivity is available. Therefore, access to the necessary information was potentially available *whenever* the student wanted to access it without reliance on public-access or departmentally supplied PCs.

The unit content

In the first laboratory session, students were given an introductory demonstration lecture to help them navigate around the VLE. This was the only time that a traditional 'teacher centred' format was used in the course. The initial activity for a student first logging-on to *WebCT* is to watch a video on laboratory safety and to complete a mandatory quiz based on the video. We therefore have a traceable, electronic record of whether a student has undertaken safety training in addition to any paper based records.

To optimise the use of laboratory time[9], we wanted students to undertake structured 'pre-lab' exercises outside formal teaching hours so that when they came to the laboratory, they would:

- be familiar with the background chemical theory involved in the experiment;
- be confident in performing any calculations involved;
- know why they are doing the experiment in a wider chemical context;
- have a good idea of the apparatus to be used and how the experiment is to be performed.

The first three of these can be achieved to some extent in a paper based 'pre-lab'. The last point though is difficult to illustrate in this manner.

To achieve our aims, each experiment has a VLE segment essentially involving four steps; a short introductory video to put the experiment into wider context, a short presentation to revise the chemical background, a video to show the practical aspects of the experiment and finally, most importantly, a short 5-10 question multiple choice question (MCQ) quiz covering all three presentations. Students were required to undertake the quiz before coming to the laboratory (with penalty if not done). This allows them to gauge their level of preparedness to undertake the experiment and to get remedial help if necessary.

One of the physical chemistry experiments involves using Hess's Law to calculate the enthalpy change for the hydration of sodium carbonate from some calorimetric measurements. The approach that we adopted is illustrated for this experiment in Figure 1.

The introductory videos illustrate several aspects of thermochemistry in industrial and everyday contexts – for example a self heating can of coffee and a highly exothermic polymerisation reaction. They are kept to short duration (2 – 3 minutes each) and are focused so as to maintain student engagement. Similar videos are also used to introduce the experimental apparatus and methods that will be used. Some generic sequences made use of some of the Computer Video Consortium (CVC) resources[11] which we had previously used on laser disk as stand alone support in the laboratory. However, to maximise the usefulness, demonstrations of the experiments were filmed using the actual apparatus which students would use. Thus, they should be familiar with how to do the experiment (or at least recognise the apparatus) before they come to the class. All of the video sequences were recorded as .avi files and stored on our network server. *WebCT* was used to launch the *Windows XP Media Player* to play the videos, allowing students to pause or rewind the film and to watch the video as many times as necessary.

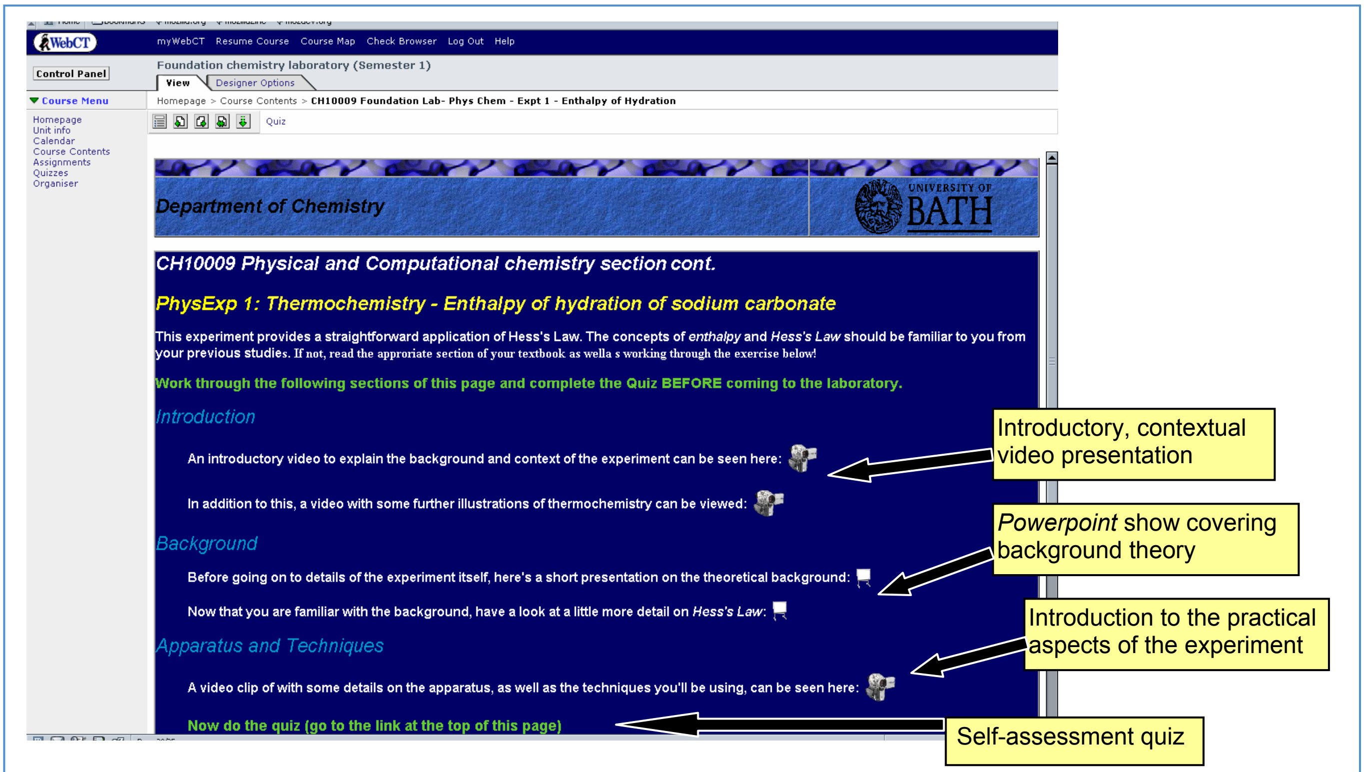

Figure 1: An introductory WebCT page for a thermochemistry experiment

Given the objectives of the unit, we selected experiments that depend on chemical topics that would have been studied before coming to university. However, it may be some time since they were studied in detail so that students work through a short (4-5 min) *Powerpoint* presentation, included embedded audio, to reinforce their background. This can also be launched from within the VLE. For this experiment, a brief reminder of Hess's Law as it can be applied to this particular reaction is presented, as shown in Figure 2

Working through these activities *should* equip students with the necessary background for the experiments. However, all of these activities could be treated passively by the student or even ignored. The final part of the 'pre-lab' exercise is therefore a compulsory MCQ quiz. This covers the background theory, practical elements and any calculations involved and so ensures that the student had engaged with each element of the package; the approach is illustrated in Figure 3. The administrative functions of the VLE make it very easy to check whether a student has attempted the quiz and completed the background work.

Feedback is provided if answers to questions are not entered correctly but this is deliberately minimalist. The point here is for the student to gauge their own knowledge. If they come to the laboratory with a secure knowledge base, they can perform the experiment more effectively and achieve its learning outcomes. If however, they identify gaps in their knowledge, students can get these addressed by staff before starting the experiment or performing calculations. In this way, staff time is concentrated where it is needed and not diluted across a whole class. While the VLE has the facility for recording student scores in these quizzes, we did not do so.

Students were required to attempt the quiz but not to achieve a required mark to emphasise that it was diagnostic in nature. However, fuller analysis of the data might indicate areas where improvements might be needed in order to enhance the package for future years.

In addition to the 'pre-lab' function, the extensive computer networking of our new laboratories allows us to make the information available during the classes. Therefore, if a student needs to check a problem, they can consult the background material instantly rather than possibly having to wait for a staff member to be available.

Further support for work in the laboratories is given by small structured presentations, for example on the estimation and treatment of uncertainties as part of the VLE package.

Evaluation and discussion
A simple comparison of students' performance on the unit with previous years is not possible since the organisation and assessment were extensively revised. This would not in any case be a good measure of whether we had met our objectives.

We invited feedback comments from students and conducted towards the end of the unit (prior to final assessment) a structured interview with all students in groups of 4-5. The interviews were not conducted by the staff teaching the unit so as to avoid potential bias. Their feedback showed that they understood the aims and objectives of our approach and felt that it was worthwhile. Most found the format more engaging than simply listening to a class presentation or watching video presentations in isolation from the experimental details.

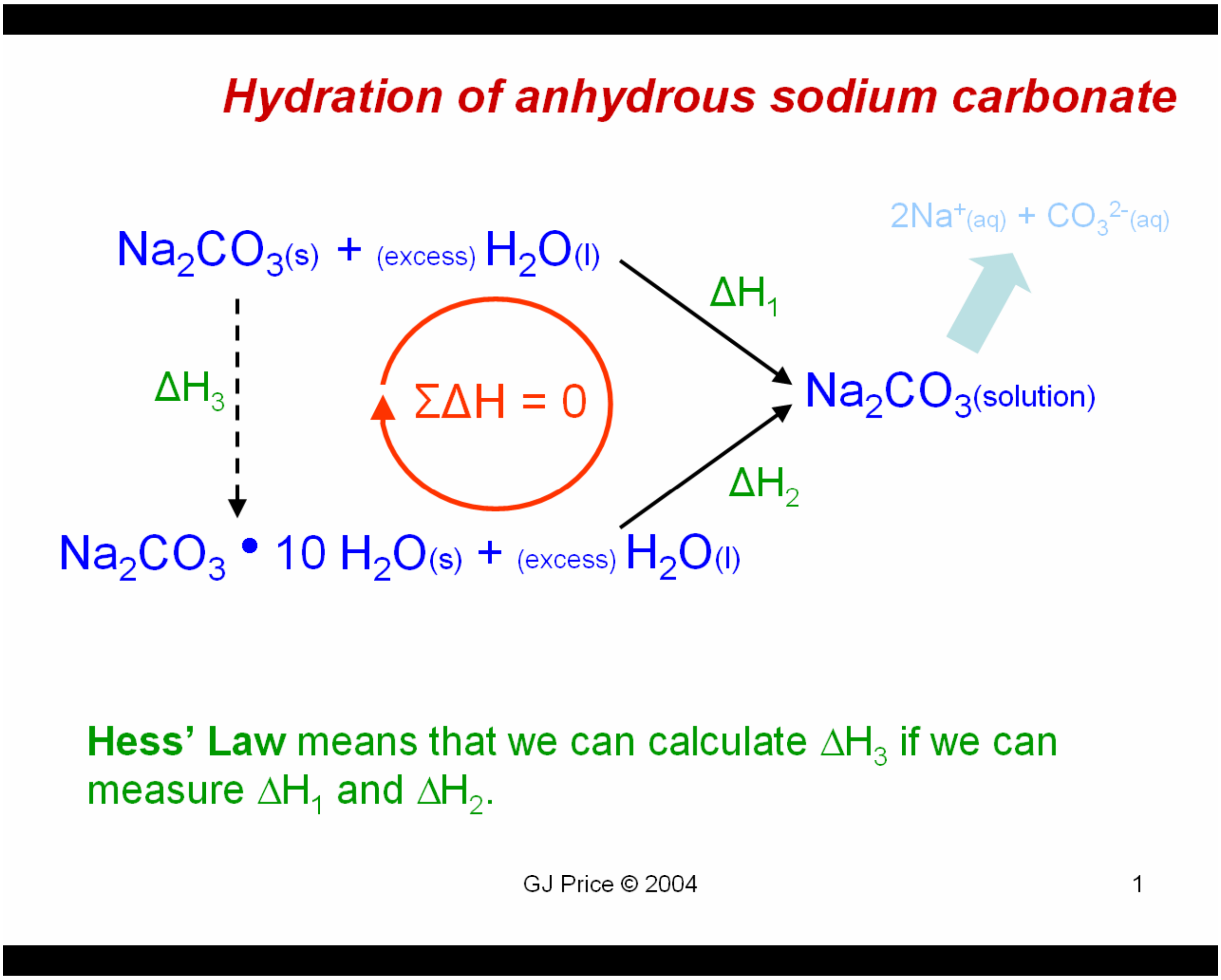

Figure 2: A reminder of Hess's Law

Students can access this as and when they are ready to process their results rather than in a class presentation at a time that may not be appropriate to their particular needs.

Inevitably, some thought there was too much background and some that it was too easy. Significantly, almost all students felt that they were adequately prepared for the experiment before they came to the laboratory.

Few students were negative in their comments about the style of the unit. An element of concern was raised by two students who felt that delivering material independently through ICT was rather isolating and did not convey the friendly, inclusive ethos that other aspects of the department's activities encouraged.

From the staff point of view, there was a noticeable improvement in laboratory performance in that less time was taken to complete experiments. Students were able to concentrate on collecting data (and repeating if necessary) rather than in assembling apparatus. Demonstrators felt that the 'quality' of students' questions was better and more focused; rather than 'where does this bit go' type questions, enquiries concentrated on how to process the results and understand the chemistry. This is precisely what we had been aiming for. Staff were also able to distribute their time and effort more effectively by spending more time with students who needed additional help rather than answering routine enquiries from a large number of students. Also of significance were comments from staff running classes following on from the Foundation module. These suggested that students' performance was improved since they were used to completing pre-lab work and starting work immediately on entering the laboratory.

Of course, much of the preparatory work could be achieved using a paper based system to cover the context and fundamentals rather than one based on ICT. However, the use of the VLE allows a more coordinated presentation of the various aspects and, in particular, an illustration of the actual apparatus to be used. This obviates the need for much of the demonstration work previously undertaken at the beginning of classes. We estimate that some 30 – 45 minutes was saved in each session. This time was then spent at the end of experiments in discussion of the results with students in small groups; a more effective use of time.

A VLE is not strictly necessary. For administrative reasons, a VLE was not available to us last year and we delivered the material to students via a series of linked web pages. The results were similar although using the VLE made integration across a network easier (eg a single log-in for students) and the monitoring and recording functions were certainly missed. From 2006 onwards, the University of Bath has adopted *Moodle* as its VLE so that we are currently investigating how this package can be used to deliver the material.

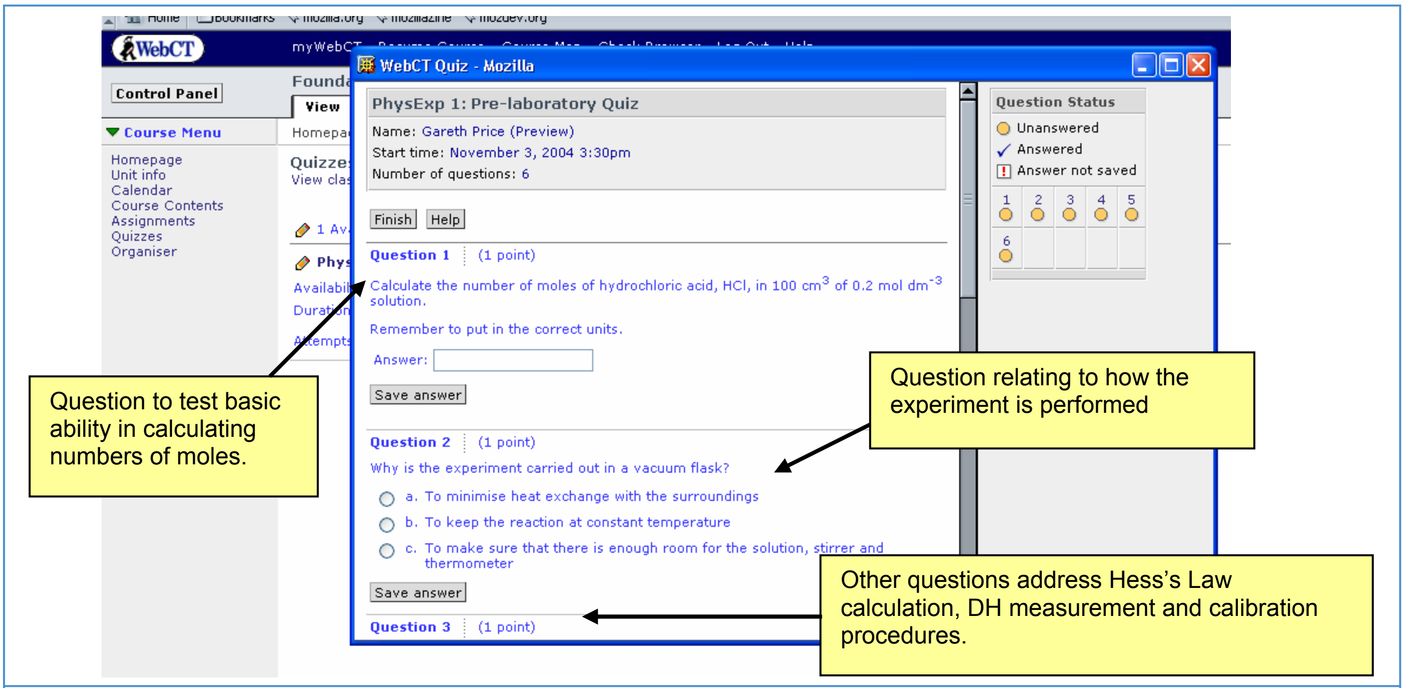

Figure 3: A self-evaluation quiz

The quiz and feedback functions of the VLE mean that students can gauge from their quiz results before coming to the laboratory whether they have a good understanding of the material and so know whether to start the experiment or seek further help. Using a paper based system, all students need to consult a member of staff before starting so that further time is saved. In principle, the VLE offers the facility for students to submit reports and practical results electronically. We trialled this but found there to be little advantage over students completing a paper proforma for marking. However, it did help in keeping track of assessments and in the unit administration.

Of course, there is a significant investment of time needed to set-up the packages. Filming, editing and recording the videos and presentations took around two full-time person-weeks. Transferring these and other documents into the *WebCT* environment took more effort. All of the various segments were stored in platform independent formats (.avi, .pps, .html) so that we are not reliant on a single VLE model. Overall the resource invested has, we feel, paid off in more effective running of our laboratory classes. Indeed, after we had put our system into place, we became aware that McKelvy[12] had operated a similar 'pre-lab' exercise using *WebCT*. Gratifyingly, our experience was similarly positive to his.

Acknowledgements
We are grateful to Dr Mark Russell for assistance with the technical aspects of combining video, audio and other files within a VLE across a distributed network and also to Dr Elaine Swift and Lisa Williams within the University's E-learning team for help with the set up of *WebCT*. Drs Andy Johnson and Simon Bedford organised the Inorganic and Organic aspects of the class and spent many hours in discussions as to how best to implement our ideas. We should also pay tribute to the late Mr Mark Price of the University of Bath AV unit for filming and editing our laboratory videos.

The quiz and feedback functions of the VLE mean that students can gauge ...before coming to the laboratory whether they have a good understanding of the material

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The Genesis of an Adult Education Programme in Science

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...we allow the public to choose which aspect of chemistry they want to learn more about, and participate in discussions with professional scientists about controversial aspects of chemistry and related scientific issues

Abstract
Science and technology are now part of our everyday lives, and their impact will undoubtedly continue to grow in ever more sophisticated and subtle ways. Inevitably, this will lead to debates and controversy about the ethics and risks that science brings with it; debates in which the general public should be fully engaged. But many adults inevitably feel alienated from any involvement in such a debate because of their lack of scientific knowledge. There is a very urgent need to engage not only young people but also more mature adults in scientific discussion at levels that are both meaningful and serious. In Newcastle we are developing an adult science education programme which brings together local adult education providers, universities and industry to supply a cohesive series of short events which not only allow adults to learn and engage with contemporary science (and how it impacts on their everyday lives), but also offers the opportunity to progress to more advanced courses leading to formal qualifications. In this article we outline the development of this programme which was greatly assisted by the appointment of an 'Adult Education Fellow' (funded by The Higher Education Academy Physical Science Centre). Over the course of one year the Fellow established the consortium, identified what the detailed demand was, prepared the course and raised funds ready for its start in 2006.

Introduction
Since about the middle of the last century the picture of the benevolent, absent minded, scientist has been replaced with a more demonic image. Issues such as nuclear weapons, pollution, global warming, genetically modified foods and stem cell research have over the last 50 years been taken up by the press highlighting the dangers of science to society. There is a growing concern about the way in which science is perceived by the general public. It is clear that the science is becoming more sophisticated and raising issues of concern to the public. But many adults feel unable to make a judgement about articles in the media; for the majority this is because they have only a rudimentary understanding of science that they learnt at school many years ago, and for some no knowledge of science whatsoever.

Scientists need to enter into a meaningful dialogue with the general public to present the impact of their work on society today and dispel the 'boffin' or Frankenstein image of scientists which has been presented. A great deal of effort in Public Awareness of Science has been targeted at school children. In contrast, science education for mature adults has been grossly neglected, despite the fact that this group is exposed to current scientific issues on a daily basis when reading newspapers or listening to radio and television. Many adults are enthusiastic to learn more about science but feel they are being left behind in the technological world. In Newcastle we are developing a Science Adult Education Programme (REACT – *R*udimentary *E*duc*A*tion in *C*hemis*T*ry) which presents one aspect of scientific development within the reach of most adults: chemistry. REACT emphasises the importance and pervasive nature of chemistry and related sciences in the world today, specifically targeting a mature adult audience who have only rudimentary scientific knowledge. We believe that, to be successful, this programme needs to involve adult education specialists working together with university-based chemists. Thus a group comprising members of the Association of Part Time Tutors (APTT), Workers Educational Association, Newcastle upon Tyne Branch (WEA) and the Chemistry Department at the University of Newcastle (NCL) originally conceived an approach which has now expanded to include a variety of other providers. This article describes our preparations for starting the programme and how it developed from a series of 'taster' events, to involve a consortium of educational providers and industry, supplying not only introductory scientific material and experiences suitable for the general public but also providing pathways leading to more advanced courses and qualifications.

Since the last war, the post-compulsory sector (comprising what is now loosely termed ‘adult education’ plus the FE colleges and university-provided HE access) has been responsible for the scientific training of adults in the period after their ‘compulsory’ education. That this has largely been ‘remedial’ in strategy is not surprising; colleges tend to mainly provide what the labour market demands, which in the vast majority of cases is GCSE and A-Level provision allowing adults to make up for ungained qualifications at school. Outside this remit, FE college courses involving pure science of any sort are thin on the ground, and have been for some considerable time. Adults are reluctant to take up study unless it either provides a pragmatically useful qualification, or adds to their hobby interests. FE courses, being targeted to qualifications, do not allow the flexibility to encourage the background discipline of scientific thought in the broadest sense. Syllabi tend to specialise in ‘must know’ theory and practice, which often deters the stimulation of casual enquiry. Consequently, most general scientific education for adult laypersons who are not intending a science career has fallen to HE extra-mural departments (for example, Sunderland University Centre for Lifelong Learning at Newcastle, CLL) and adult and community learning bodies such as WEA, APTT, etc. Government financial support for all of these however has been meagre.

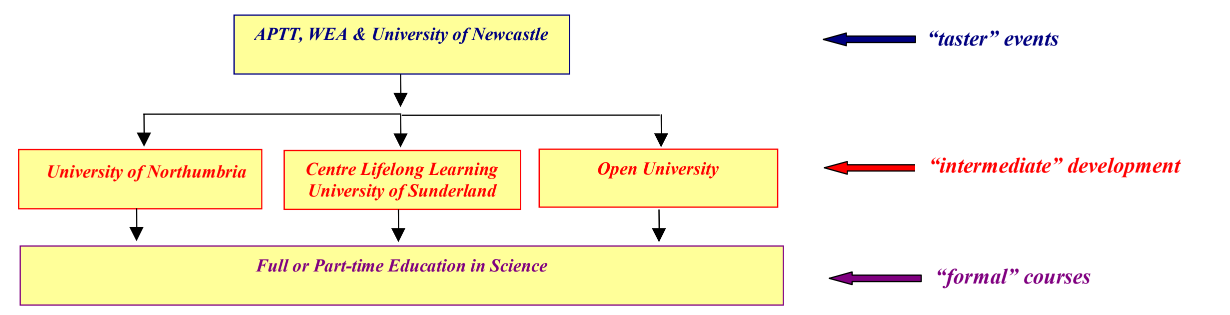

Figure 1: Representation of the progression pathways in the Adult Science Education Programme indicating the various providers.

Subsidising what has often been characterised as ‘leisure’ learning has been politically unpopular, and hence declining funding has pushed up the cost of all non-FE provision. This increasingly market-led environment has led to fewer adults trying out new and unfamiliar topics, such as science.

Initial Objectives

Even with declining funding, adult education providers have tried to encourage scientific study. The WEA Northern Region has a long tradition of offering non-accredited accessible introductory courses and Day Schools. Recent ‘Days’ on even supposedly ‘difficult’ topics such as quantum mechanics and cosmology have attracted substantial attendances (15 to 18 students per course), which indicates that, given the right presentation level and teaching style, it is possible to enthuse adults about even the most esoteric of scientific concepts. WEA Newcastle upon Tyne Branch was willing to chance its arm by funding what seemed thorny science subjects, and encouraged the tutor concerned to promote science as part of existing courses in history of ideas and philosophy. Due to confidence in the WEA method of learning, adults were willing to take on board these initiatives – with the pleasing outcome described above. In addition, the WEA’s links with CLL allowed progression from these non-accredited events to certificated study at foundation HE, or into related areas of technological study offered by APTT (Association of Part-Time Tutors). The overall message this experience brings is that once adults have been suitably enthused and their confidence raised, then there can be a demand for growth of serious scientific training. However, it is fostering this initial state of enthusiasm (in effect, forming a ‘community of practice’) which is fundamental to defending scientific knowledge amongst laypersons.

When first developing a Science Adult Education Programme the initial objective was simple: to supply ‘taster’ events lasting only a couple of hours, where participants would not only be presented with the salient facts pertinent to selected contemporary scientific issues, but also have the opportunity to discuss the issues as they saw fit. To this day, these remain the project’s principal objectives. But on further reflection, achieving these goals required the presentation of a cohesive series of such ‘tasters’, all with the common theme of science. Furthermore, there were two other features necessary to raise the educational credibility of the programme. First, that the participants experience working in a laboratory. This will allow participants to have a greater appreciation of the ways scientists operate and how hypotheses are proposed and tested by experiments. Secondly, to provide further support and more advanced courses for those participants who were sufficiently enthused by the ‘taster’ events. The educational process necessitates that enthusiastic participants should have an outlet for their increasing enquiry, and potentially could take progressively more advanced study. This required the involvement of other adult education providers.

Development of the Programme: Involving other Education Institutions and Industries

The funding from The Higher Education Academy Physical Sciences Centre allowed appointment of an ‘Adult Education Fellow’ (Dr Sundus Henderson) who spent 1 year developing the Science Adult Education Programme. Thus, after a series of meetings, the following institutions became associated with the programme: Centre for Lifelong Learning, University of Sunderland (CLL); University of Northumbria (UoN); Open University (OU); Procter and Gamble (P&G) and Centre for Life, Life-Lab (LL). Thus, APTT, WEA, NCL, P&G and LL will be involved in presentation of the ‘taster’ events, whilst CLL, UoN and OU already offer a few more advanced science topics which would be suitable for those participants of the ‘taster’ events who wish to continue their studies.

Question	Summary of Responses
(1) Please tell us about any science learning you have undertaken in the past.	There was more interest from those who had previously done more than one science subject. 97% of replies studied at least one science subject in a structured setting but only 29% of those were actually interested in the subject and only 58% obtained a qualification.
(2) Please tell us if you would consider taking part in courses/ discussions/ experiments to discover the truth and myths behind the following subjects, in the next 3 years.	The most interest was shown in 'Medicinal Plants' and 'Food and Risk'. Other popular topics were 'The West's Fuel', 'Genealogy', 'Understanding Evolution', 'Water', 'Weapons of Mass Destruction' and 'Jewels from the Earth'.
(3) How do you like to learn?	Attending a talk/lecture is the most favoured method of learning followed by group discussion. Computer related learning scored low maybe due to the fact that most scientific learning requires observation and demonstrations of experiments.
(4) Please tell us which of these statements you agree with. (Statements about importance of science and preferred learning patterns).	91% agreed that science is part of life long learning; 88% like being with other learners; 81% agree that chemistry forms the basis of most of their households; 68% agree that learning chemistry is easier if it relates to their lives; 66% prefer to learn at set times each week.
(5) When do you learn best?	78% prefer learning in the morning which could reflect that most applicants are economically inactive (retired/unemployed) or have flexible working hours.
(6) What stops you from learning about science?	Work commitment (47%) was the major barrier to learning.
(7) How far would you be prepared to travel to take a course?	63% of applicants do not mind travelling 7-10 miles to attend a learning event.

Table 1: Summary of the Responses to the Questionnaire.

Furthermore, the involvement of a recognised multi-national industrial company, such as Procter & Gamble, exposes the participants to the industrial and commercial side of science leading to a broader appreciation of how science impacts on their everyday lives. By working together, the assembled consortium can offer provision in chemistry and related sciences, and additionally enable educational progression for adults across the whole range of scientific subjects. The participants of the Science Adult Education Programme can gradually build participants' scientific knowledge and with it their enthusiasm and confidence to (if they wish) re-enter full or part time education with the aim of obtaining formal qualifications in science. The range of provision offered by the consortium is illustrated in Figure 1.

Delivering what is Wanted.
In order to establish what aspects of science the adult public are most interested in attending and how they would like to be taught, a short questionnaire was constructed which contained seven general questions with a selection of tick boxes for answers.

The full questionnaire can be found on the REACT web site at www.REACT.no-ip.com, and the key findings are summarised in Table 1. The responses to the questionnaire guided our design of the 'taster' events which are shown in Table 2.

'Taster' events principally comprise 2-3 hour workshops in which participants will learn about science through presentations, demonstrations, debates and discussions on selected topics. However, 'taster' events will also involve visits to university laboratories (University of Newcastle) to experience 'hands-on' practical chemistry and industrial laboratories (Procter and Gamble) to experience industrial chemistry. In addition, The Life Lab (LL) currently runs short introductory courses on topics such as Forensic DNA for the general public which are suitable for the participants of the 'taster' events. By offering a wide range of short courses and lecture/demonstrations we allow the public to choose which aspect of chemistry they want to learn more about, and participate in discussions with professional scientists about controversial aspects of chemistry and related scientific issues. Many of the topics in the adult programme have been chosen particularly to attract women.

Theme Title	Title of Taster Event	Brief Summary
The West's Fuel	Weapons of Mass Destruction (WMD) – What are They?	A look at the science of WMD emphasising the early history of chemical weapons.
	The West's Fuel	Petroleum refining – the antecedents, the chemical processes and political implications.
	Food and Risk	A look at genetic modification of food and the perceived risk to the public.
	Drugs and Sporting Achievement	How the body functions at the chemical level and how this might be enhanced.
Summer Events	Poisonous Plants – from Magic and Murder to Medicine	In collaboration with Alnwick Gardens Poison Plants display. The role that plants have played in medicine, including some contemporary uses of plants.
	The Laboratory Experience	An afternoon in which participants will perform selected chemistry experiments.
Earth Matters	Give me Sunshine: How the Sun Shines and Where the Chemicals of Life were Made.	How the Sun maintains its output of energy and created carbon and oxygen and other elements.
	Jewels from the Earth	A look at the origin of gemstones; their chemistry and the creation of jewellery.
	Chemistry and Cosmetics	The way chemistry is used to improve our looks and smell.
	Understanding Evolution	Examination of how life has arisen and is maintained by chemical processes.

Table 2: Summary of the Taster Events

The Next Stage: Presentation of 'Taster' Events
In the first instance we are offering 'taster' events in central Newcastle, North Tyneside, Gateshead and South Tyneside, especially focusing on areas where adult education is generally neglected or under-supported. This has been made possible by the award of an Engineering and Physical Sciences Research Council (EPSRC) Partnerships for Public Engagement grant. We will use a combination of local venues around the area. The first series of 'taster' events were held in the CLL which is situated in the centre of the city.

There will be an emphasis on familiarising adult participants with university life and 'hands-on' experience in chemistry. Advice and guidance will be given by the tutors to help participants further their scientific knowledge. Courses on more advanced science topics are already offered by CLL, UoN and OU. For example, the 'Science and Environment' programme of CLL contains courses which link in very closely to nearly all of the 'taster' events. Discussions with CLL have resulted in CLL planning new courses for 2006 to provide opportunities for participants of the 'taster' events to progress into more in-depth, HE level courses. The OU currently offer broad-based science courses, such as, 'Another Breakthrough in Mathematics, Science and Technology' (Y155) as well as more focused courses, such as, 'Food and Health – A Chemical Story' (S191). The UoN offer courses entitled, 'Chemistry, Plant Biology and Ecology, and Sports Science'.

After local piloting we anticipate that the programme will be expanded to national level, given suitable resourcing.

Acknowledgements
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A Resource for Introducing Molecular Modelling into the Undergraduate Chemistry Curriculum

Abstract

Computational methods including molecular modelling are becoming an essential aspect of chemistry. As such there is a pressing need to introduce this methodology at the undergraduate level. In this communication we give our experience of developing an appropriate course using formal lectures and practical workshop sessions. The emphasis is on practical applications. While the essential background theoretical aspect is introduced it is recognised that overemphasis and reliance on theoretical understanding can discourage many students. Our approach is to treat molecular modelling similarly to spectroscopic interpretation where an intelligent interpretation of an NMR spectrum does not always require a deep appreciation of background NMR theory.

Introduction

Over the past few years, molecular modelling has evolved from a specialised research tool of limited availability to an important and essential means of chemistry exploration. Software to perform molecular modelling is now widely available on desktop PCs using ubiquitous operating systems such as *Microsoft Windows*. This widespread availability can now be exploited to introduce molecular modelling into the undergraduate curriculum.

While the mathematical background to certain molecular modelling tools, such as electronic structure calculations, can be daunting this also applies to spectroscopy which has been taught for many years at undergraduate level. The key is to teach molecular modelling as a practical tool. In this respect learning to use modern graphics based molecular modelling software is certainly no more difficult than learning to operate an IR or NMR spectrometer. In essence the student needs to be able to appreciate intelligently the type of information that can be obtained from molecular modelling and to recognise its limitations. The student can achieve this by a practical hands-on approach.

...the vast majority of students found the resource of significant use and it greatly increased their appreciation of molecular modelling

Molecular modelling can be used therefore to learn and understand chemistry. It can do this in isolation or in combination with experimental approaches. Molecular modelling can be used to explore relationships between molecular structure and molecular properties. This theme of structure property relationships pervades almost every stage of a chemist's education.

Description

While numerous textbooks exist on theoretical chemistry there are very few textbooks which teach molecular modelling directed specifically at undergraduate level. This is partly due to the arrival only very recently of suitable software for such purposes available campus-wide. It is therefore of benefit to have a resource introducing the background to the principles involved accompanied by a series of practical exercises. This material can be used unaltered or adapted to suit a particular emphasis.

Lecture material in the form of *Powerpoint* slides is therefore accompanied by workshop exercises to be completed using *Gaussian 03* and *Gaussview*. The *Gaussian* program is the leading electronic structure software both in academia and industry; *Gaussview* is a graphical interface to the program allowing molecular preparation and graphical display of calculated molecular properties. Both programs are made available on a campus site - license at reasonable cost.

Content
The lectures cover introductory molecular modelling and computational chemistry. Major topics covered include:
- General introduction to the methods of computational chemistry
- Extension from qualitative molecular orbital methods to qualitative methods
- Types of electronic structure methods available
- Practical aspects of performing electronic structure calculations as opposed to detailed theoretical foundations
- Choice of level of electronic structure theory
- Basis set definitions and explanations
- Factors influencing choice of basis set
- Factors to consider in choosing an appropriate method
- Interpreting output from electronic structure calculations
- Graphical representation of orbital electron density, spin density and electrostatic potential
- Geometry optimisation
- Calculation of vibrational frequencies
- Methods for evaluating charge distribution and their performance
- Calculation of spin densities and hyperfine couplings
- Transition state calculations and their characterisation
- Fundamentals of molecular mechanics
- Forcefield expressions for a typical forcefield
- Minimisation
- Conformational Analysis
- Molecular dynamics

The workshop exercises are aimed at enhancing the lecture content, stimulating the students and providing practical hand-on training.

Examples from the workshops are shown in Figures 1 and 2.

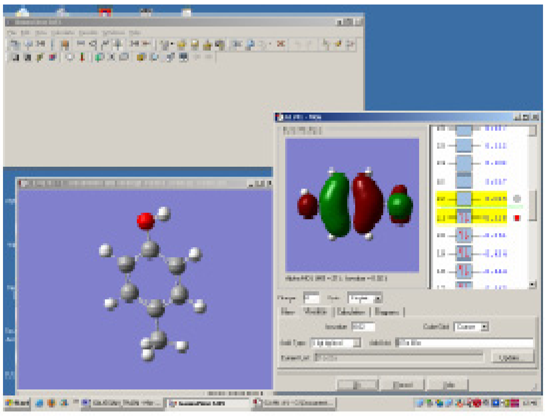

Figure 1: Displaying molecular orbitals using Gaussview

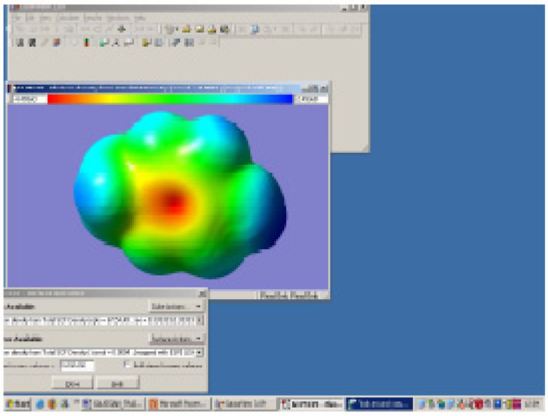

Figure 2: Displaying electrostatic potential using Gaussview

Feedback/Evaluation
The resource was used in the teaching of molecular modelling at the School of Chemistry in the academic year 2005/2006. Based on completed student questionnaires the vast majority of students found the resource of significant use and it greatly increased their appreciation of molecular modelling. The availability of parallel practical workshops to the lecture material helped the students appreciate the applications of the technique to real problems. Many students also took the opportunity to use the *Gaussian* software loaded on the University network to explore some of the more advanced workshop aspects in their own time. In addition I have had contacts from students outside Manchester commenting on the usefulness of the workshop exercises in learning how to use the *Gaussian* program.

For more information
http://www.manchester.ac.uk/chemistry
or more specifically
http://www.chemistry.manchester.ac.uk/staff/staffprofile.php?un=omalley

Science in the virtual learning environment as more than online conversation

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For further information, more examples of online activities or assessment and online discussion grading rubrics please contact the author.

Face-to-face lectures redesigned to incorporate communications technology are valued by students who appreciate the more flexible opportunities for student-student, student-tutor communication and peer-to-peer support.

Abstract

The asynchronous computer conference still finds itself largely ignored as an effective vehicle for supporting student-centered, collaborative learning experiences. When it is employed the quality of the learning experience varies widely. The literature reports students either unengaged with the medium or overwhelmed by the discussion threads. The online discussion itself tends to take on the nature of an accumulation of independent facts and little peer-to-peer engagement.

It is recognised that learning environments in introductory science courses play a crucial role in Higher Education, and dialogic inquiry is understood to play a vital role in the study and understanding of science. According to Biggs[1] "constructively aligned" learning environments in which careful attention is given to the relationship between learning outcomes, learning activities and teaching practice and assessment strategy are supportive of inquiry.

Based on a series of introductory online physical science modules, designed and taught by the author for the University of Maryland University College (UMUC), it is shown that an aligned virtual learning environment is feasible and supports deep learning. Key factors instrumental to the successful delivery include clear communication of tutor and student role, ample opportunities for social networking and a range of creative learning activities and meaningful assessment tasks. The asynchronous conference plays a central role in which ideas are not only shared but critically examined and improved. Interaction goes far beyond conversation, reaching a deeper level of collaborative inquiry and ultimately knowledge construction[2].

Science educators are encouraged to incorporate asynchronous conferencing to undergraduate science courses with the aim of fostering collaborative inquiry and critical thinking skills. The case study demonstrates that if the above described features are realised in the online design, the asynchronous conference by default becomes the showplace for knowledge construction from the outset and increasingly the students' major learning resource[3].

Summary

The asynchronous discussion tool provided by a virtual learning environment (VLE) is an effective vehicle for supporting student-centred, collaborative learning experiences. We include here computer, online or asynchronous conferences and also discussion boards or forums. The online contributions, however, often tend to take on the nature of an accumulation of independent facts and demonstrate little if any peer-to-peer engagement. It is suggested that this is due to a range of factors including misconceptions about the role of the tutor, inadequately prepared students, and inappropriate tasks, largely unaligned to learning outcomes.

This case study will demonstrate how the asynchronous conference can be employed in a range of imaginative ways not only to extend lecture or seminar time to support lively, collaborative inquiry in introductory physical science courses, but also to prepare students for laboratory practicals and to encourage peer-to-peer support. Engaged activity on the asynchronous discussion board can contribute to a deeper understanding of the fundamental concepts and relationships that undergraduate science students often struggle with. Thoughtful preparation and careful alignment to the face-to-face lecture activity help secure students' active online participation, under the premise that the tutor is visibly online as well.

Introduction
It is recognised that learning environments in introductory science courses play a crucial role in Higher Education, and dialogic inquiry is understood to play a vital role in the study and understanding of science. According to Biggs[1] "constructively aligned" learning environments in which careful attention is given to the relationship between learning outcomes, learning activities and teaching practice and assessment strategies are supportive of inquiry. Teaching practice that encourages students to take a deep, rather than a surface approach to learning (as opposed to a surface approach) unleashes higher level cognitive processes that see the student actively engaged in the learning activity rather than passively receiving information.

Based on a series of fully online environmental science modules, designed and taught by the author, it has been previously shown that an aligned virtual learning environment is feasible and supports deep learning[4]. Key factors instrumental to the successful delivery include clear communication of tutor and student roles, ample opportunities for social networking and a range of creative learning activities and meaningful assessment tasks. In this the asynchronous conference plays a central role in which ideas are not only shared but critically examined and refined. Interaction goes far beyond conversation, reaching a deeper level of collaborative inquiry and ultimately knowledge construction[2,3].

The asynchronous conference is a more flexible means of communication that, used to extend the physical sciences lecture or seminar discussion time, provides added opportunity for reflection. It also gives all students, in particular the reticent and the non-native English speakers, a more equal footing. Despite widespread belief otherwise, students are often lacking the required technical and communication skills. By paying careful attention to these, the asynchronous conference is employed to enhance the lecture, becoming the showplace for engaging, collaborative scientific inquiry. In the light of the recent emphasis on active learning and on a constructivist approach to science education in order to improve understanding[5], embedding the asynchronous discussion board into existing teaching strategies can provide a means of meeting a more learner-centred approach to teaching.

By posing imaginative, probing questions that encourage students to think about principles and concepts outside of the classroom context, students apply rather than repeat knowledge and become engaged in lively exchange.

Description
Case Study
All the teaching and learning activities described here have been created and supported by the author over the course of 5 years for a fully online undergraduate physical science module, which served as an introduction to the basic principles of physics, chemistry, astronomy, and geology. Students studied the relationships among the physical sciences and the role each of these sciences plays in interpreting the natural world. There was no content placed online beyond a topic-related weekly introduction. The online module was activity and communications driven, knowledge construction largely taking place collaboratively in the asynchronous discussion board. All tasks and quotes presented here represent actual events on the discussion boards over the course of one semester.

The majority of tasks had originally been developed to support the author's face-to-face physical science or inorganic chemistry lectures in a so-called 'blended' delivery mode, the basis for the recommendations in this paper. Slightly modified, the tasks were found to lend themselves equally well to support students on fully online modules. Both modes enjoyed a lively online participation rate in which an average of 85% of the students engaged with the online activities. In most instances it was found that the level of inquiry and understanding was positively influenced by activities carried out on the asynchronous discussion board.

Uses of the asynchronous discussion to support face-to-face teaching
Education research has found that the standard lecture can be an ineffective way to actively engage students with the lesson material, students often not reaching deeper levels of understanding[1]. (Employing a variety of learning modes recognises the different ways in which students learn and promotes a more stimulating learning experience). The asynchronous discussion tool of virtual learning environments (VLEs), for example, used to support the face-to-face lecture and seminar, can serve to create an active and collaborative online learning environment[6]. Examples that will be introduced in this paper include:

1. Directly linking an online task to enhance lecture activity
2. Extending time for collaborative learning, enquiry, and debate
3. Facilitating a theme-related problem solving forum
4. Supporting group work activities
5. Supporting simple 'kitchen chemistry' tasks.

Preparation

The key to the success of the online discussion as a supplementary venue for any of the uses in the above list is its thoughtful preparation. Any attempts at discussion or debate later on will be thwarted if students have not first had the opportunity to familiarise themselves with the VLE, the discussion tool and the nature of online communication. The degree of comfort students feel about learning online plays a key role for the success of any online tool, but this is particularly the case for communications tools. Students often feel inhibited to contribute online for fear of appearing less knowledgeable than their peers, especially given that the written record of the discussion is usually permanently available to the whole class for the duration of the term.

Key strategies for preparing and nurturing a trusting learning environment that are borne out by the learning and teaching experiences in the case study are listed below.

1. Be there:

Before even considering to include online communications technology to support your teaching, be sure that you have the time to provide online support, guidance and prompt (within 24 hr) feedback. Merely creating a discussion board online and announcing its arrival to students in the lecture as an additional area to, 'Go and discuss' will not encourage anyone to use it.

Box 1: Examples of questions that worked

Topic: Newton's Laws of motion

"Suppose you are standing on the ice of a frozen lake and there is no friction whatsoever. How do you get you off the ice?"

Topic: Free fall

"Imagine an air resistance-free world. A raindrop formed in a cloud at an altitude of 4000 m. Estimate the speed at which it would hit your head in freefall."

Topic: Fluid mechanics

Sitting next to you on your transatlantic flight to Lisbon, a little girl exclaims, "Cool, it's magic, my gummy bear packet is in-flating!" You the studious physical science student (and of little pedagogic skill) disillusion her with a simple scientific explanation. Which one?

2. Give it meaning:

In your module guide or syllabus make it very clear from the outset that you will be using the online discussion tool to support your face-to-face teaching. Emphasise the purpose of the online discussion and explain clearly the role of the technology, the role of the student and the role of the tutor. For example, consider awarding grades for online participation based on the quality of the contributions. For an example of an effective method adopted by the author[7] to manage students expectations, go to 'Myths about taking online classes' at http://polaris.umuc.edu/de/ezine/features/jan_feb_2004/demyths.htm (Note, that this was aimed at the fully online students, however many elements apply to the blended approach as well.)

Box 2: Students online activity

Students enjoyed the questions and often matched the fun. Each of the questions listed stimulated a flurry of online activity, questions and exchange between students. Student posts included remarks such as,

"OK, I am beyond confusion now and need some help with this equation!"
"I don't know, but I hope someone can tell me."
"Classmates…in need of some serious help and direction here."

which often prompted other students to help out creating a dialogue of collaborative inquiry often beginning with remarks such as:

"At first, I completely agreed with Thomas, but….."
"I see it your way, Jan……"
"Michael, believe me you are not the only one confused here. I think the answer…"

Appeals directed at the tutor included,

"Christina, am I even close?"
"I honestly have no idea how you keep those equations straight."

By going online, over the course of one week students and tutor were given more time than otherwise available to collaboratively reflect on and solve a wide range of problems in a supportive and trusting learning environment.

3. Give it constructive alignment:

By carefully aligning online communication tasks to face-to-face lessons, students recognise the purpose and meaning of both and are more inclined to participate. For example, the results of an online inquiry that informs the subsequent lecture will see more students actively engaged with it than otherwise the case.

4. Give it rules:

Fruitful online communication and learning depend on a common understanding of an encouraging written tone and mutual tolerance and respect. Post Netiquette (online etiquette) guidelines and remind students to adhere to them. Limit the word count of posts to allow for equal opportunities of response. Be a role model to the above. Limit the length of time for which the discussion board is available in order to facilitate a rich and focused exchange of thoughts and ideas.

5. Give it time:

Long before the online discussion activity is to take place it is recommended that a discussion area is prepared to allow students to become accustomed to the discussion tool and to one another, online. An introductory discussion activity related only loosely to the module materials has been shown to set the right tone from the very start. A question like, "Can you give an example in which a myth or legend has been proposed to explain a natural phenomenon" is one that most students can contribute to, requiring little prior physical science knowledge yet linked to the subject under study.

Challenge students to guess the number of water molecules in a snowflake or send them to the Scientific Method quiz at http://antoine.frostburg.edu/chem/senese/101/intro/ for example, and then post their results in the online discussion area. Be there to demonstrate interest and concern.

6. Give it a surprise:
Give students a reason to login other than just to pass the course. If science is fun, then why not demonstrate that? During a lesson about the natural elements, share with unsuspecting students links to the Periodic Table of Comic Books (at http://www.uky.edu/Projects/Chemcomics/), weave in some science trivia such as Christmas goose thermodynamics, for example, or engage them with the reflex tester (at http://www.happyhub.com/network/reflex/) easily linked to a physics lesson on reaction time. Simple things, like placing a thoughtful quote from a famous scientists (such as “Pick a flower on Earth and you move the farthest star.” from Paul Dirac) in a dry lesson on Newton’s Universal Law of Gravitation, can go a long way.

Examples of uses of the asynchronous discussion to support teaching
The underlying design goals for the majority of the tasks described below was to excite students for physical science and to encourage critical thinking skills. By instilling in students a sense that physical science is fun, exciting and relevant to their daily lives, they become more motivated and active in their learning and are more likely to continue their studies.

Stimulating activities that are relevant to the learners’ interests, and tap into existing knowledge, enhance the learning experience. This approach to teaching is not only central to the constructivist perspective, but lends itself particularly well to the online learning and teaching environment. Online activities that are directly aligned to the lectures give participation in both added relevance and purpose. Face-to-face lectures redesigned to incorporate communications technology are valued by students who appreciate the more flexible opportunities for student-student, student-tutor communication and peer-to-peer support. Advantages for the lecturer include better use of time in the classroom (improved ‘time on task’), flexibility of teaching, improved student-tutor communication, and global outreach.

1. Directly linking an online task to enhance lecture activity
Example: Atmospheric chemistry lesson
The NASA (National Aeronautics and Space Administration) website at http://www.nasa.gov/home/ provides a huge range of educational resources, one of which is the Total Ozone Mapping Spectrometer (TOMS) website at http://toms.gsfc.nasa.gov/ozone/ozone_v8.html. In a face-to-face lecture on stratospheric ozone, the tutor assigns students each a country above which to retrieve the ozone layer thickness using the online resource, *Ozone Overhead*, at http://toms.gsfc.nasa.gov/teacher/ozone_overhead_v8.html. For large lectures (n>100) it is recommended to assign countries to groups of students. Students publish their data online (eg, in the VLE) which forms the basis for a moderated online discussion after comparing and evaluating figures for thickness within the context of the face-to-face lesson. The activity is easily taken further by assigning students (or student groups) to monitor and chart their region’s ozone layer thickness for a number of weeks comparing this to last year’s NASA data, for example, and making predictions for the future. Students have access to spectroscopic data, from wherever they can go online which might be at the institution, their place of work or at home.

Box 3: Tutor online activity
The main challenge for the undergraduate science tutor is how to spark initial interest and then encourage, prompt and build confidence in order to maintain that interest. Online, the logoff button is never far away! Equally important for a problems based learning environment described above, is to make it so 'safe' to make mistakes that students recognise making mistakes a natural part of their (deep) learning. This is a particularly precarious undertaking online in a subject area such as physics for a chemistry major, for example, but more so worthwhile given the lack of skill students entering HE have and the minimum timeframe lecturers struggle to fit their curriculum into.

In the physical science context of fundamental principles, concepts and theorems it becomes the online tutor’s responsibility to monitor online activity and step in and gently correct where necessary, always maintaining an encouraging tone.

For example, to address a misunderstanding the class has:

“Well, you all have demonstrated a good understanding of Boyle’s Law, but what about forgetting to deflate the tires of a bike stored in the (unpressurised) belly of a plane……?”

Or to encourage one student to rethink a response or calculation:

“Hmmm, careful-do remember that for free fall the equation is………… Would you try it again? Anyone else willing to help us out?”

“James, thanks for trying! Now let me ask you, in your calculation for the kinetic energy, what did you use for v?”

The website enriches the core textbook and lecture by visually demonstrating the concepts under discussion. NASA also makes available an online textbook, Stratospheric Ozone (http://www.ccpo.odu.edu/SEES/ozone/oz_class.htm). Learners are offered a combination of visual and interactive elements that enable them to better grasp the basics of ozone layer depletion. In addition the learner takes an active role in learning by engaging in research related tasks such as data gathering and analysis, problem solving and authentic enquiry.

2. Extending time for collaborative learning, inquiry, and debate
Carefully chosen web resources and relevant websites broaden the range of information available to the student and can easily convey a sense of interrelatedness between the sciences, encouraging students to make new connections on their own as well. Employing online communication tools extends the time available for critical discussion and debate, creating engaging experiences for collaborative learning that might otherwise not be realised in the setting of traditional teaching.

In the following example, a geology lesson goes beyond exploring the formation of rocks or the chemical composition of minerals, by tapping into environmental science issues to which the students can directly relate and explore in the online discussion board.

Example: Geology lesson

In a geology seminar students are prompted to consider factors contributing to the depletion of natural resources. The ensuing debate is subsequently carried out online in the asynchronous discussion board over the period of the following two weeks.

The nature of the question is crucial for stimulating online discussion. Open-ended questions that spark interest and controversy work well, for example. In the case study the following question proved very successful: “Population growth is said to be at the root cause of resource depletion. Consider the proposal by an industrialised western nation to make foreign aid conditional upon the stopping of population growth by the poor, overpopulated recipient nations“.

Students were directed to visit two websites (Facing the Future, at http://www.facingthefuture.org/, and Population Studies, at http://www.pop.org/) that clearly support opposing views, which formed the basis for critical class discussion, first face-to-face and then online. They were also encouraged to draw from additional hard copy or online resources at their disposal. This online activity supports conceptual learning, objective analysis, collaborative learning, and collective decision making.

Give students a reason to login other than just to pass the course. If science is fun, then why not demonstrate that? During a lesson about the natural elements share unsuspecting students links to the Periodic Table of Comic Books...

3. Facilitating a theme-related problems solving forum

For students struggling with fundamental concepts in physical science or mathematics the asynchronous conference can offer a flexible and collaborative means of support. Online, students can reflect longer about problems as well as draw from each other, rather than solely from the tutor, to assist their understanding. By posing imaginative, probing questions that encourage students to think about principles and concepts outside of the classroom, students apply rather than repeat knowledge and become engaged in lively exchange (see boxes 1: ‘Examples of questions that worked’, 2: ‘Students online activity’ and 3: ‘Tutor online activity’).

4. Supporting group work activities

The use of case studies teaches physical science to students within a ‘real’ life context. Case studies relate course material to real world scenarios the student can identify with and lend themselves particularly well to online learning by putting the student at the centre of the learning process. Within the context of a group work assignment, students are prompted to find solution pathways in collaboration with other students, and by making use of a variety of resources. This could be lecture material, readings from the core text, websites or e-books.

When presented as a case study, the asynchronous conference can serve as the students’ area for collaborative online group discussion adding flexibility to group tasks otherwise constrained by the time and place for all group members to meet face-to-face. The asynchronous conference can be used in combination with the synchronous chat and could be linked to a collaborative working space, such as a wiki. Group projects can be published online for viewing by all, and a class discussion board then serves as the showplace for peer review and class debate, for example.

The biggest online databank of science related case studies free to use by all practitioners is the University of New York at Buffalo’s Case Studies in Science[8] repository at http://ublib.buffalo.edu/libraries/projects/cases/ubcase.htm#pharm/. The JISC supported Resource Discovery Network (RDN) also maintains a small collection of case studies at http://www.rdn.ac.uk/casestudies/.

5. Supporting simple ‘kitchen chemistry’ tasks

Practicals designed so that the only materials required can be found in a household, can also be useful to illustrate selected principles of physical science. Hands on experiments introduce the scientific method and its practical application to science as well as to everyday questions and problems. A typical activity might include preparing a homemade pH indicator from red cabbage juice, etching a series of metals (Cu, Zn, Al, Fe) with a salt-vinegar solution or a felt tip pen chromatography experiment carried out on coffee filter paper with a variety of readily available household solvents.

Each laboratory description is posted in the asynchronous discussion board together with any online resources such as the interactive periodic table website (at http://www.chemicalelements.com/), helpful simulations, or 3-D models. Students are encouraged to share experiences of collecting material, designing the experiment and recording any observations online. In the interest of promoting problem solving skills a move away from the ‘cookbook’ instruction format is recommended, clearly formulating the learning objectives instead and leaving it to the students to identify and collect materials and to design the experiment. Students have proved themselves most resourceful (in one instance using a cigarette carton as a measuring device) and regularly share apparatus and observations by uploading digital images and video clips for the rest of the class to see online.

Additional uses

1. Preparing students for face-to-face laboratory classes

Creating an online discussion board in which experimental procedures, pitfalls and safety concerns are reviewed beforehand saves valuable laboratory time (and glassware). Students are better prepared for laboratory activity after engaging with safety and procedural related questions posted online, which they can solve together supported by a teaching assistant, for example. Virtual chemistry laboratory safety tutorials are also available from UK web resources such as the national electronic repository, Education Media OnLine (EMOL) which has recently become Film & Sound Online (http://www.filmandsound.ac.uk/)

2. Questions forum

The creation of an online questions forum for any course related questions (eg, timetable, assignments), together with a clear 'private inquiries only' email policy stems email inbox traffic markedly. After a few courses, compiling an online FAQ list reduces all inquiries even further. It is crucial here that response time is kept to a minimum.

3. Socialisation space

In large lectures especially, students tend to remain either anonymous or locked into smaller peer groups. By making an informal online socialisation space available students have the opportunity to communicate with all class members at their own convenience. Students recommend books and movies to one another as well as exchange good and bad learning experiences, which can result in a supportive network of learners. Clearly indicate that this is a non-moderated online discussion area.

4. Starting small

As shown above, the asynchronous conference can be used in a wide variety of ways to support the physical science lecture: nevertheless, it is recommended to start 'small'. Consider maintaining a discussion board as a questions forum in the first instance, in order to familiarise yourself with discussion threading and online communication. Invite students to share a science web resource or two with the class on a discussion board. Visit the sites and return comments to the contributor, which acknowledges the student's online efforts and gives you the opportunity to practice posting. There is no need to embed the asynchronous conference into your teaching until you feel comfortable and confident enough to do so, which will also ensure that your students have a positive and rewarding online learning experience.

Conclusion

Science educators are encouraged to incorporate asynchronous conferencing imaginatively into undergraduate science courses as a meaningful and flexible supplement to the face-to-face lecture. By doing so it has been shown that collaborative inquiry and critical thinking skills are supported, which ultimately contribute to the students' enthusiasm for the physical sciences. The case study demonstrates that if prepared thoughtfully, the asynchronous conference can be instrumental in actively engaging students with the material and supporting a deep understanding of the concepts and principles of physical science.

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Context based learning in chemistry: Chemistry in Sport

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Abstract
A learning resource for part-time 1st year foundation degree students was designed to be completed entirely by independent study. The course presented chemistry in the context of sport and investigated the use of a number of alternative methods of teaching/ learning, including:

- *The Perry Scheme of Intellectual Development*
- *Multiple intelligences (MI) Theory*
- *Problem-Based Learning (PBL)*
- *Context Based Learning (CBL)*
- *Mind Mapping*
- *Case Studies*
- *Web-based independent learning*

A website containing questions, hyperlinks to further content and external webpages was produced.

The students' response was positive. They enjoyed the course, found the context interesting and the presentation helpful. The assessment marks improved (a 5-6% increase) compared to a more traditional paper based course. As only eight students took the course these results cannot be seen as statistically significant but provide a good indication that this was an effective approach.

In completing their assessments and pre and post questionnaires the students provided valuable feedback that will enable improvements to the learning resource.

The resource was designed with built-in flexibility so that each section could be used individually to supplement other areas of the chemistry curriculum.

Introduction
The use of a real life context to teach chemistry has been shown to enhance levels of student engagement and enthusiasm for learning[1-4]. Margetson[5] stresses the value of knowledge and skills acquired in context. Coles[6] reports that students who see the interconnections and links between different knowledge areas gain the highest scores in examinations which tested that knowledge and were more able to retrieve and use the information they had learnt. Coles sees context as essential for elaborated learning. For elaborated learning to occur students must be given the opportunity to relate what they now need to know to past experiences and prior knowledge. Within a context, Coles says, students will be able to better see their task as "linking together aspects of knowledge both within and between subjects, and relating what they are learning now to what they already know". Coles concludes that "elaboration is unlikely to occur under the conventional curriculum arrangement, and does not necessarily occur during problem-based learning*"*. He proposes a more general model of education called contextual learning, suggesting that elaboration can occur if students have: an appropriate context for learning; information or access to information potentially relatable to that context and opportunities to handle the information in order to make connections. In cases where students are given an appropriate context they report 'things coming together'. Rogers[7] says context provides a motivating force for the student through which the student develops a wish to know more and wants rather than needs to learn.

In arguing the case for teaching chemistry in context Hills[8] identifies the fact that most current scientific knowledge is explicit ie factual precise data. Implicit knowledge is personal, emotional, not yet defined and not scientific. This implicit knowledge is generally ignored in science and students are only examined on their explicit knowledge. Hills argues that this depersonalisation removes much of the interest in scientists and in science itself.

Context-based learning resources can be presented as problem solving case studies. According to Belt and Phipps[1] case studies can be used to address a range of skills, develop a mode of thinking, working and communicating, and are best done by tackling open-ended problems. Overton[3] states that students undertaking problem- and context-based courses show that there are many benefits to be gained from this approach. Students' motivation, attitude to study, long-term retention of knowledge, use of resources, key skills and success as postgraduates are all significantly superior when compared to students taught by conventional methods.

Although many learning resources are made available via the web, a limited amount of research has been carried out on its effectiveness as a learning tool. Arasasingham et al[8] assessed large numbers of students on their understanding of stoichiometry using a web-based assessment program. With a group of students using textbooks and paper to complete the assessments as the control group, they were able to compare the web- and non-web-based approaches. The assessment results found that the web-based students outperformed the non-web-based students and showed greater conceptual understanding. The students using the web-based course also reported that having to work independently with the program forced them to work harder on the subject with the pay offs being instant feedback and greater understanding.

We aimed to use the benefits of context based learning presented as a case study on the chemistry of sport with the advantages of using the web for independent study.

Chemistry in Sport
The learning resource developed was a case study on the applications of chemistry in sport. The target students were part-time chemistry undergraduates without timetabled support for the module and with limited access to the library, so the teaching method had to be tailored to an independent learning approach. The resource provided the students with content and they were given tasks throughout. The tasks were designed to enhance understanding and extend the content already presented. Many of the tasks were open ended without a definite right or wrong answer, and the students had to support and defend their answers.

As sport pervades modern popular culture, it was decided to use the applications of chemistry in sport as the context. Interest in the context would be a 'way in' to the subject matter, prompting a motivation to learn on the part of the students.

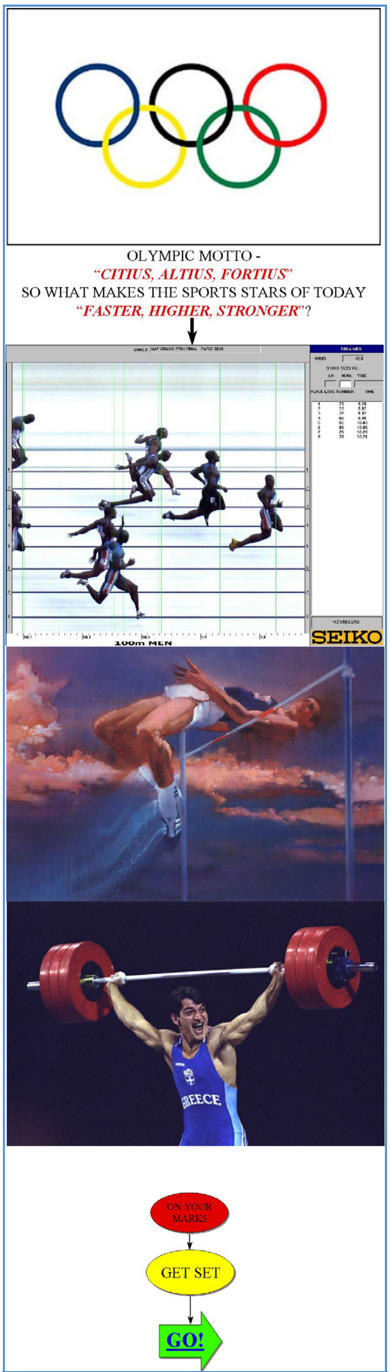

Figure 1: Homepage

The learning resource comprised three sections. The first looked at the use of performance-enhancing drugs from the point of view of detection and was, therefore, primarily concerned with analytical chemistry. The students were asked to look at the cases of three British athletes who had recently been involved in drug scandals. In recent years, the methods employed to detect performance-enhancing drugs, and the validity of those methods, have courted as much controversy as the cases themselves. Each case had called into question the techniques of detection, and highlighted the problems involved in the detection of performance enhancing drugs.

The second section focused on the three energy systems present within muscle cells and was, therefore, primarily concerned with biochemistry, focusing on the biochemical precursors to muscle movement and the ways in which athletes legally supplement these.

The final section investigated sporting equipment and materials chemistry. Carbon fibre and Kevlar were identified as materials frequently used in sporting equipment, and the production, structure and application of these materials was investigated.

The resource was designed with built-in flexibility so that each section could be used individually to supplement other areas of the chemistry curriculum.

Presentation
The overall structure of the course was visualised using a mind mapping software called *Inspiration* (ver 7.5 Intl.). As well as text, the software could display pictures, diagrams and links between ideas and concepts. The *Inspiration* software was capable of producing an HTML document from the collection of hyperlinked mind maps. This enabled us to present the resource as a website, and content could then be linked to external websites containing relevant information for background and further reading, putting the content further into context and informing the students' learning.

The Olympic motto is "citius, altius, fortius" (faster, higher, stronger) The introductory page of the learning resource posed the question: "what makes our sports stars faster, higher, stronger?" (see Figure 1). A screenshot of the introductory page is shown in Figure 2. A summary of the learning resource content and tasks can be found in Table 1.

Results

Before the students began the course they were asked to complete a pre-course questionnaire. The results show that, although relatively inexperienced at carrying out independent study, the students were reasonably confident about their ability to study this way. Despite only half of them having used PCs in such assignments they were confident working with computers, and about information retrieval using the internet, but somewhat less confident using the library. The group showed a range of experiences with respect to online learning.

About 3 weeks after handing in their assignments the students were given a post-course questionnaire. Overall the responses to the questionnaire were positive, and showed that the majority of students had been reasonably confident about carrying out the assignments. They enjoyed the experience, found the subject matter interesting, found the presentation helpful, and retained most of the content 3-4 weeks after completing the course. They thought that the learning method was effective, especially in comparison to the more traditional paper-based approach to independent learning, which they had encountered during the previous semester. Some students commented on the fact that a paper-based version of the learning resource would have been more convenient, since being web-based necessitated regular and reliable internet access. This was an issue as not every household had these facilities and, being part-time students, they had restricted access to the on-campus PCs.

The students' assessment results were encouraging. The marks for the continuously assessed, year long module of which 'Chemistry in Sport' formed half, averaged 67% in the first semester and 65% in the second semester. By comparison, the marks for the examined modules for that year for the same group of students averaged marks of 54% and 51%. This sort of increase in marks for a continuously assessed module is commonplace and expected.

Since the data comes from a sample of only eight students, it cannot be seen as statistically significant but provides some indication that this was an effective approach.

Figure 2: Introduction to the content

The students' assessed responses from this course showed that effective independent learning had occurred.

A copy of the resource is available from the authors.

A fuller account of this project is published in *Chemistry Education: Research and Practice*, Vol 7 (2006).

Content	Tasks
Drug use in sport, *case studies and history*	Choose athlete/learn case details/background reading
Drug use in sport, *nomenclature and use*	Find drug classes and effects
Drug use in sport, *analytical techniques used for THG, nandrolone & EPO*	Identify problems in analysis of chosen case
	Reasons for methods of analysis
Drug use in sport, *analytical instruments used for THG, nandrolone & EPO analysis and associated side effects of abuse*	Identification of health risks
	Closer look at analytical techniques for chosen case
	Closer look at problems in analysis
Energy systems in muscle cells of humans	Background reading
ATP; *energy producing biochemical*	Find chemical structure
ATP; *energy characteristics*	Find reaction and compare energy characteristics
Oxygen energy system; *aerobic glycolysis*	Predict products of reaction
Lactic acid energy system; *anaerobic glycolysis*	Predict products of reaction
Lactic acid energy system; *lactic acid build-up*	Summarise training techniques
ATP-CP energy system; *Creatine phosphate*	Find purpose of chemical in energy system
	Find and show functions of reaction
Muscle fuel; *types and sources of carbohydrates and electrolytes*	Give examples of saccharides
	Calculation of energy required from food
	Calculation of molarity of a sports drink
Energy systems; *summarisation of concepts learnt in this section*	Assigning energy systems to sporting events and justifying answers
Sporting equipment	Information retrieval
Materials chemistry; *synthesis and use of Kevlar and carbon fibre*	Account of uses of Kevlar and carbon fibre in production of materials used in sport

Table 1: Resource content and task details.

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Industry-Linked Context-Based Chemistry Practicals

Abstract
There is considerable evidence that the use of tangible contexts enriches the learning experience for students. In view of this, the author has developed two 'industry-linked context-based chemistry practicals' that illustrate the importance of core chemistry topics within commercial/industrial contexts. A common feature of the practicals is that the students work with actual commercial samples and compare their data with that published by the two companies. The principal features of the two practicals are described and contrasted with conventional practicals. Finally, the results of a student evaluation of the practicals are reported.

1. 1st Order Kinetics and Photochromism
This practical employs a number of commercial photochromic dyes from James Robinson Ltd (http://www.photochromics.co.uk/index.htm). These colourless dyes become coloured when exposed to UV light and the colour fades thermally when the UV light source is removed. The observed colour and kinetic behaviour of the dyes are sensitive to the molecular structure, environment and temperature. The dyes have applications in ophthalmic lenses, security applications and novelty items. The experiment involves measurement of UV-VIS spectra of the colourless and coloured forms of the dyes and the dye fading kinetics. The students are able to compare their kinetic and spectroscopic data with data published by James Robinson on their website.

2. An Investigation of the UV Absorbing Properties of Commercial Organic Sunscreens
This practical employs three commercial organic sunscreens from DSM Nutritional Products (http://www.dsm.com/en_US/html/dnp/personal_suncare.htm) and involves measurements of UV absorption spectra, molar absorption coefficients and the investigation of spectral changes resulting from exposure of the sunscreens to UV light. In addition to learning about the Beer-Lambert law and UV spectrophotometry, students also learn about the mechanisms by which organic sunscreens operate, their molecular structures, industry-specific jargon and units, and the biological effects of exposure to different types of UV radiation. Students compare their measurements with data published by DSM. An additional feature of the practical is the use of an on-line sunscreen simulator provided by CIBA (https://www.cibasc.com/pccibasunscreensimulator/), which requires registration before use. Students formulate their own suncreams on-line and save the results as a pdf file. They then have to extract information from the data sheet in order to determine the UVA protection factor (Boots star rating).

The use of real-world contexts has the potential to enhance the scope of a practical in terms of what students can learn and do

Introduction
There is considerable evidence that the use of tangible contexts enriches the learning experience for students[1-4]. In view of this, I recently developed two 'industry-linked context-based chemistry practicals', each of which focuses on core chemistry topics within commercial or industrial contexts. A common feature of the practicals is that the students work with actual commercial samples and compare their experimental data with that published by the companies. The principal features of the two practicals are described and future developments to the practicals are discussed in the light of student feedback and my own observations.

1. 1st Order Kinetics and Photochromism
A context-based chemistry practical highlighting the pivotal role of kinetics in commercial applications of organic photochromic dyes.

Sunglasses that darken in the sunlight and revert to near colourless in subdued light are familiar to most of us and constitute the most widely known application of the phenomenon known as photochromism[5]. What is not so familiar however is the pivotal role that chemistry plays in this fascinating and often spectacular phenomenon, and also the diverse range of applications and potential applications that exist beyond the ophthalmic lens market (eg fuel markers, security inks and packaging, cosmetics and fashion, electronic nanotechnology)[6-8].

Although the first photochromic sunglasses used silver halide technology, more recent developments have focused on organic photochromic dyes, particularly spiro-naphthoxazines and naphthopyrans (Figure 1). James Robinson[6-8], based in Huddersfield, has been actively involved in the development of such molecules since 1990 and currently markets a range of photochromic dyes under the Reversacol trade name (http://www.photochromics.co.uk/index.htm).

This practical employs a number of Reversacol photochromic dyes in toluene solution. The dyes become coloured when exposed to UV light and the colour fades thermally when the UV light source is removed. Spiro-naphthoxazines and naphthopyrans can be visualised as being composed of two planar components held at right angles (Figure 1). The photochromic effect arises from an electrocyclic ring opening that enables the two components to occupy the same plane resulting in extended p-electron de-localisation (increased conjugation) and a consequent shift of the spectral absorption into the visible region. The reverse reaction is usually thermally driven, but in some cases can be driven by visible light, and proceeds at a rate that is dependent on numerous factors including molecular structure, temperature and the molecular environment. Structural modifications such as variation of peripheral substituents enable chemists at James Robinson to fine-tune the spectroscopic (ie colour) and kinetic properties of the dyes according to the requirements of the application. In solution the reverse reaction usually follows first order kinetics, but the kinetic behaviour in other environments such as polymers and plastics can be more complex.

What struck me when I first explored the possibilities of using photochromism as the basis for an undergraduate chemistry practical is the crucial importance of the spectroscopic and kinetic properties of the dyes for applications in the ophthalmic lens market. It is clear that amongst the desirable properties of photochromic dyes for use in ophthalmic lenses, rapid colouration combined with an acceptable fade rate is a high priority. In addition, the temperature dependence of the fade rate, which can affect the depth of colour achieved under constant illumination, should ideally be minimal. Here is an example of a commercial application of synthetic organic chemistry that depends on exercising control over physicochemical properties (kinetics and spectroscopy). Specifically, the importance of fundamental kinetic parameters (half-lives, rate constants, activation energies) as determining factors within a tangible industrial/commercial context was attractive.

The Practical

Undergraduate experiments based on the kinetics and spectroscopy of photochromic dyes are not new (see for example, Prypsztejn and Negri[9]). However, I thought that such a practical could be significantly enhanced if it involved the students working with actual commercial dyes. Inspired by a *Chemistry in Britain* article[6], I contacted James Robinson who kindly supplied samples of some of the Reversacol photochromic dyes in addition to valuable feedback on the proposed practical.

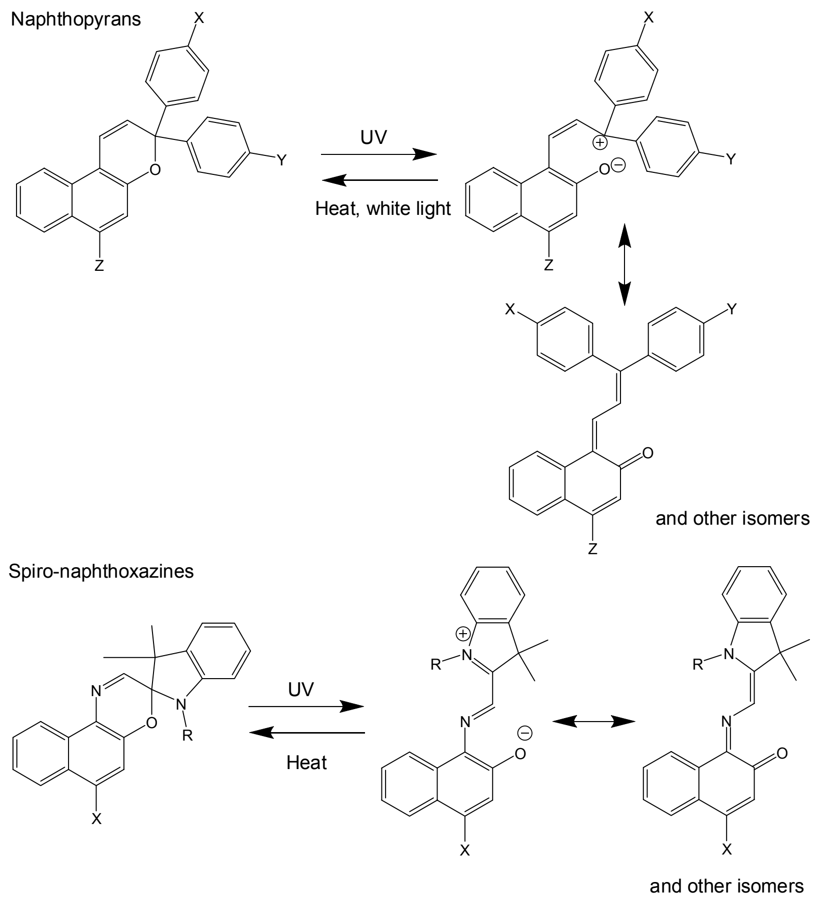

Figure 1: Generic structures of the colourless and coloured forms of spiro-naphthoxazine and naphthopyran photochromic dyes. Adapted from reference 7.

An advantage of using commercial samples is that a wealth of information resources are accessible via the James Robinson website (http://www.photochromics.co.uk/index.htm) and this facility thus enables students to gain some insight into the chemistry and applications of photochromism as well as comparing their experimental data with the data published by James Robinson.

What does the practical involve?

The practical shows how an understanding of 1st order kinetics and spectrophotometry are important within an industrial context and also how this understanding aids interpretation of technical product data. It is used in the first year chemistry course at Keele University, but is highly flexible and easily adaptable to suit students at other levels.

Some of the chemical topics and principles that the practical highlights include:

- The relationship between spectral absorption profile and colour.
- Analysis of 1st order kinetic data.
- Analysis of the temperature dependence of rate constants.
- Influence of changes in p-electron de-localisation on absorption spectra.

In its present form the practical involves:

- Acquisition of UV-VIS absorption spectra of the colourless and coloured forms of the dyes.
- Analysis of first order kinetic data (Measurement of the rate constants and half-lives for the fading of the coloured forms of the dyes.
- Investigation of the temperature dependence of the fade rate and measurement of the activation energy for the fading process of one of the dyes.
- Chemical structure drawing.
- Use of online resources available on the James Robinson website.
- Comparison of acquired data with spectroscopic and kinetic data published by James Robinson Ltd.
- Exposure to the variety of chemical structures used for organic photochromics, their spectroscopic and chemical properties and how they work.
- Exposure to some of the applications of photochromism and how kinetic and spectroscopic considerations are important for these.
- Exposure to technical jargon and terminology used in the industry.

Equipment and Materials
UV-VIS spectrophotometer, flashlight or UVA lamp, quartz cuvettes, thermometer. HPLC grade toluene. Solutions (~10^{-4} mol dm^{-3}) of various Reversacol photochromic dyes dissolved in HPLC grade toluene.

Results
Pre-Lab Work: The James Robinson website provides some excellent general information on photochromism as well as a number of informative articles available as pdf files from the 'news' link. Using these resources students are asked to find a definition of 'photochromism' and some information relating to current/potential applications.

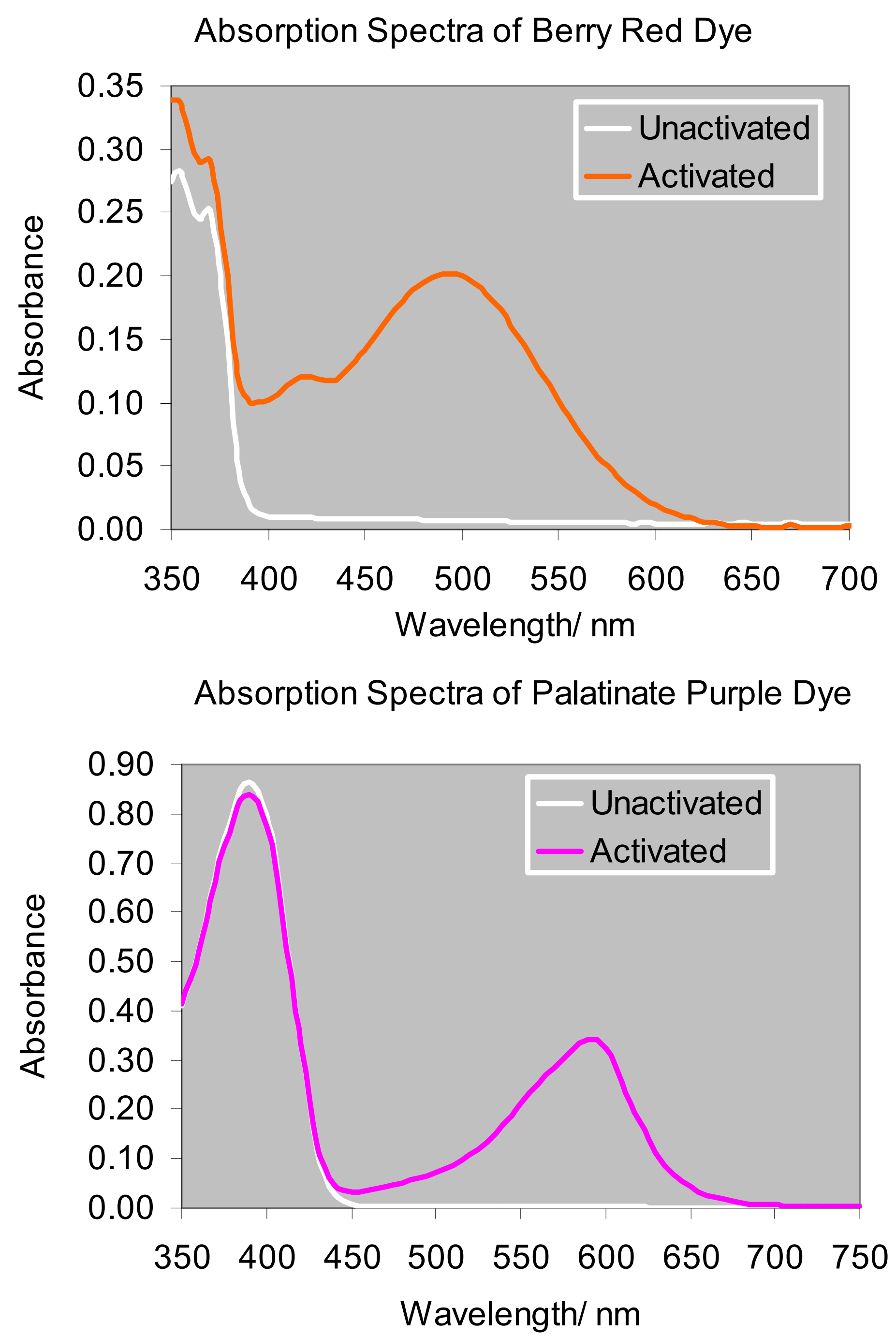

Figure 2: Absorption spectra of Reversacol photochromic dyes (~10^{-4} M in toluene).

UV-VIS Absorption Spectra: For the colourless forms of the dyes this is a straightforward aspect of the practical. However, using a scanning spectrophotometer to record the spectrum of the coloured form of the dye is more challenging, particularly for dyes with short half-lives (the half-lives vary from ~10 s to >100 s at room temperature) as the dye fades significantly as the spectrum is being acquired. This can cause an apparent shift in the position of the absorption maximum (l_{max}) when compared with the James Robinson data, but the shift is small (a few nm). It is also important to achieve uniform colouration of the solution throughout the cuvette, which is best achieved by stirring during or immediately after illumination. The solutions are effectively ‘coloured up’ using a handheld UVA lamp or flashlamp. Students compare their l_{max} values with those published by James Robinson on their website. Representative spectra are shown in Figure 2.

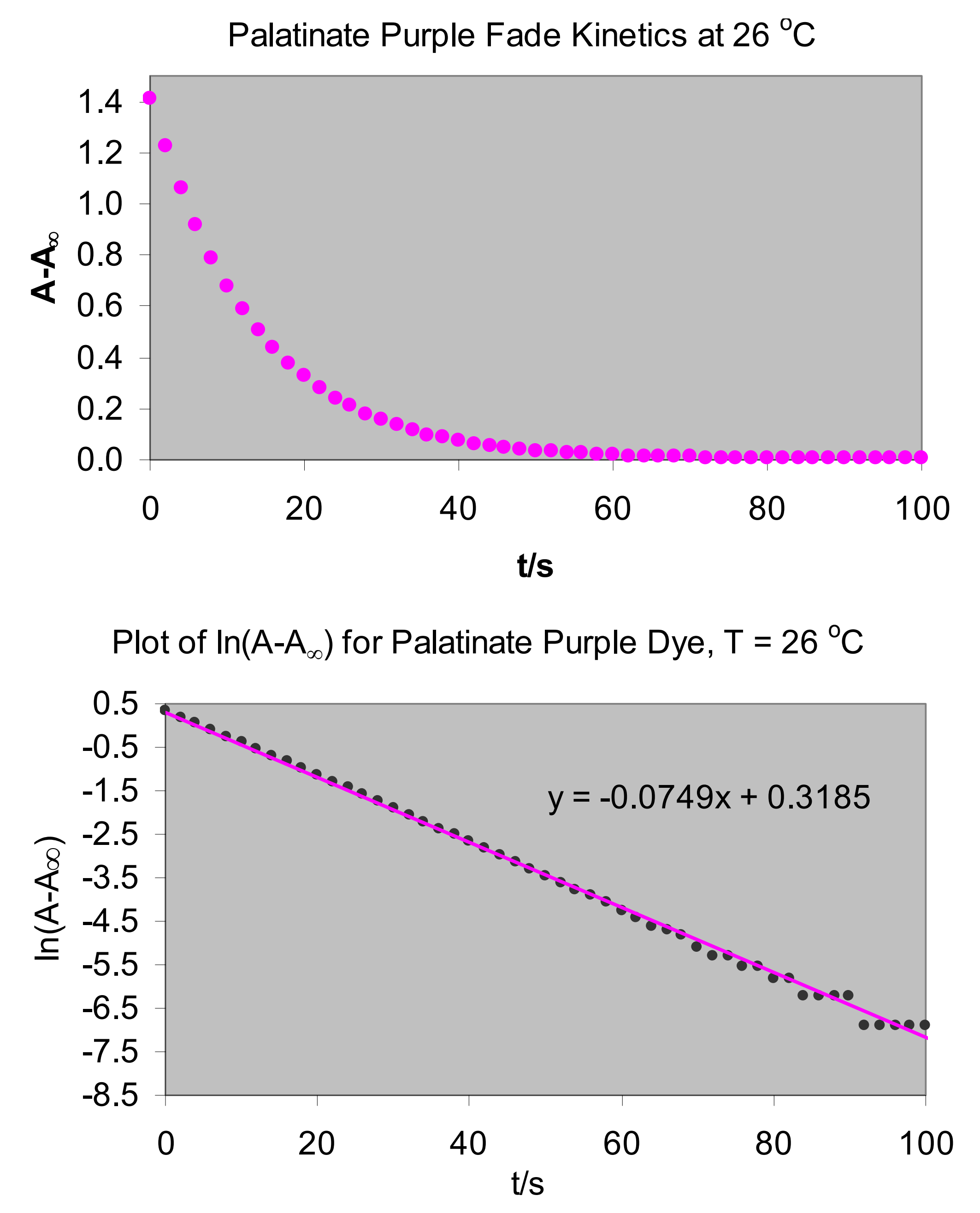

Figure 3: Kinetic data for the fading of a photochromic dye (Reversacol Paltinate Purple in toluene at 26 °C).

Fade Kinetics: Having located the λ_{max} of the coloured forms of each of the dyes students then set the spectrophotometer to this wavelength and record the fall in absorbance with time. Here students have to exercise judgement over the data collection interval and total data collection time. As before, it is important to achieve uniform colouration throughout the entire volume of solution within the cuvette. As we do not have sufficient temperature control apparatus for the number of students in the class at Keele, the kinetic measurements are performed at ambient temperature, which is recorded. For the majority of dyes the fade kinetic are 1st order in toluene solution and the analysis of the absorbance versus time curves involves manipulation of the data on a spreadsheet to plot $\ln(A-A_\infty)$ versus t, where A_∞ is the final absorbance at thermal equilibrium. The slope of the resulting linear plot is –k from which the half-life is easily obtained. Representative data is shown in Figure 3. The students compare their half-lives with the values published by James Robinson, noting of course that the James Robinson values pertain to 20 °C. Temperature dependence measurements involve a method based on initial rates.

Student Feedback

The student feedback on the practical was generally very positive. Representative student comments include:

Photochromism: What did you like about this practical?

- I like the dyes. I haven’t seen these kinds of dyes before. It’s good to know how chemistry is applied in our lives.
- Very interesting, good experiment to do as is completely new.
- Using the lamps to change the colour of the solution.
- It was interesting and different.
- Something new.
- Interesting and the way the chemicals changed colour under UV.
- The vibrant colours of the dyes.
- Very helpful in understanding lectures – kinetic graphs etc.
- Enjoyable.
- Saw reaction right in front of us.
- We got to organise our own experiment.
- Experience in using spectrophotometer for rates.

Photochromism: What did you dislike about this practical?

- I didn't know what I was doing during the experiment.
- It was a bit monotonous after a while.
- Difficult to find information.
- Repetitive.
- Waiting around while data being collected.
- The maths.

Conclusion
From a combination of the student feedback (including anecdotal feedback) and my own observations it is clear that the students find the practical novel and interesting, but that perhaps they are being overloaded with information and being asked to do too much of the same thing. One of the implicit aims of the practical is that students see why kinetic considerations in commercial applications of photochromism are important and I would like to have clearer evidence that the students make such links. This may be best achieved by the design of pre-laboratory and/or post-laboratory activities that require students to apply their knowledge in a commercial context. Future development of the practical will therefore focus on improvements to the design of pre-laboratory and post-laboratory work and a review of the overall information and work load.

2. An Investigation of the UV Absorbing Properties of Commercial Organic Sunscreens

A context-based chemistry practical highlighting the pivotal role of UV absorption spectra, photoisomerisation, the Beer-Lambert law and molar absorption coefficients in commercial sunscreens.

Organic sunscreens function in variety of ways, but a common feature of all organic sunscreens is that they are designed to be highly efficient and photostable UV absorbers that are able to dissipate the absorbed energy rapidly, efficiently and harmlessly as heat[11]. The sunscreens used in this practical achieve this through photo-induced geometrical (E-Z or cis-trans) isomerisation and each displays a strong absorption band that peaks in the UVB region (290-320 nm).

The practical employs three commercial organic sunscreens (Figure 4) from DSM Nutritional Products (http://www.dsm.com/en_US/html/dnp/personal_suncare.htm) and involves measurements of UV absorption spectra, molar absorption coefficients and investigation of spectral changes resulting from exposure of the sunscreens to UV light. In addition to learning about the Beer-Lambert law and UV spectrophotometry, students also learn about the mechanisms by which organic sunscreens function, their molecular structures, industry-specific jargon and units, and the biological effects of exposure to different types of UV radiation. Students compare their measurements with data published by DSM.

An additional feature of the practical is the use of an on-line sunscreen simulator provided by CIBA (https://www.cibasc.com/pccibasunscreensimulator/), which requires registration before use. Students formulate their own suncreams on-line and save the results as a pdf file. They then have to extract information from the data sheet in order to determine the UVA protection factor (Boots star rating).

The Practical
UV protection and sunscreens provides a versatile real-life context that is suitable for a wide range of educational activities at various levels (see for example, Abney and Scalettar[10]). The design of this practical was largely informed and inspired by my previous research on the photochemistry of sunscreens[11-13].

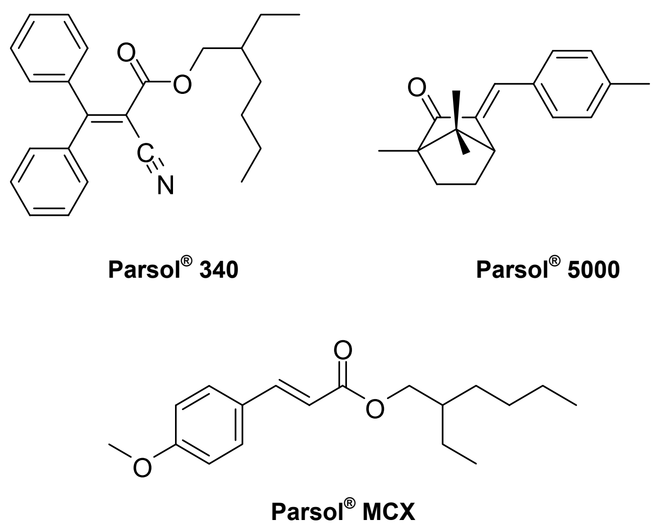

Figure 4: Structures and DSM trade names of the three UVB sunscreens.

What does the practical involve?
The practical shows how an understanding of the Beer-Lambert law and UV spectrophotometry are important within a commercial context and also how this understanding aids interpretation of technical product data. It is used in the first year chemistry course at Keele University, but is highly flexible and easily adaptable to suit students at other levels. Some of the chemical topics and principles that the practical highlights include:

- Classification of different UV regions.
- UV absorption spectroscopy.
- Application of the Beer-Lambert law to determine molar absorption coefficients.
- A sense of scale for molar absorption coefficients.
- Inter-conversion of units.
- Photoisomerisation.
- Influence of geometrical isomerisation on absorption spectra.
- 'Photostability' in the context of sunscreens.

In its present form the practical involves:

- Measurement of the UV absorption spectra of the three sunscreens.
- Application of the Beer-Lambert law for the determination of the molar absorption coefficients of the three sunscreens.
- Investigation of any modifications to the UV absorption profile of the sunscreens as a result of inducing photoisomerisation by exposure to UV light
- Use of the Ciba on-line sunscreen simulator to formulate a sunscreen and obtain SPF and UVA protection factor information in addition to spectral data.

Equipment and Materials
UV-VIS spectrophotometer, quartz cuvettes, UV (313 nm) light source (at Keele we use *foster + freeman VSC4c video spectral comparators* from our Forensic Science laboratory) but sunlight can of course be used, if available. HPLC grade methanol and ethanol. Solutions of accurately known concentration (~10^{-4} mol dm^{-3}) of the three sunscreens dissolved in methanol or ethanol.

Results
Pre-Lab work: In preparation for the practical the students are required to find out the wavelength regions corresponding to UVA, UVB, UVC, Visible and IR radiation and the relative proportions of these penetrating the atmosphere to sea-level. The students also learn about the differing biological effects of UVA and UVB radiation, the different UV absorption properties of glass and quartz and they also carry out serial dilution calculations.

UV Absorption spectra: The students acquire the absorption spectra of the three sunscreen solutions and compare the l_{max} values with those available from DSM. The student data is consistent with that reported by DSM to within ±2 nm.

Determination of molar absorption coefficients: The students use autopipettes and/or conventional pipettes to prepare a series of solutions of varying concentration (typically 10^{-5} – 10^{-4} M) by accurate dilution of the stock solutions in 5 ml or 10 ml volumetric flasks. They then record the absorption spectra of the different solutions and plot absorbance at l_{max} versus concentration to determine the molar absorption coefficient from the slope. Typical data is shown in Figure 5

DSM report molar absorption coefficients as 'UV specific extinction' values. These values represent the projected absorbance of a 1% solution of the sunscreen in a cuvette of 1 cm pathlength. Therefore, to compare their results with DSM students need to convert the units of their own value or the DSM value. Converting the DSM value involves translating the 1% solution into molarity and then applying the Beer-Lambert law to obtain e in dm^3 mol^{-1} cm^{-1}. For Parsol 340, DSM quote a UV specific extinction in the range 340-370, which converts to 12,291-13,375 dm^3 mol^{-1} cm^{-1}, in good agreement with the slope for the data in Figure 5

Investigation of spectral changes induced by exposure to UV light: Here the students investigate whether spectral changes occur as a result of exposure to UV light. It should be noted that the results for this part of the experiment are somewhat dependent on the properties (eg spectral intensity profile) of the UV light source used, but the effects are apparent using natural sunlight (of course, because glass absorbs UVB you have to open the window, or go outside). At Keele the students expose the sunscreen solutions in quartz cuvettes to 313 nm UV light from a video spectral comparator for short (~10 s) intervals and record the absorption spectra after each exposure. Model data is shown in Figure 6.

An important principle of the operation of these types of sunscreens is illustrated by this part of the experiment. Where the two geometrical isomers are different (Parsol 5000, Parsol MCX) then the exposure to UV light leads to the development of a photo-stationary isomer mixture with a resulting modest modification to the UV spectral profile of the solution that reflects the fact that the two isomers have slightly different UV spectra. The precise composition of the photo-stationary mixture is dependent on numerous factors, and not least the properties of the UV light source. The important point is that a photo-stationary mixture is quickly established and it is this mixture that exhibits photostability in that its spectral profile

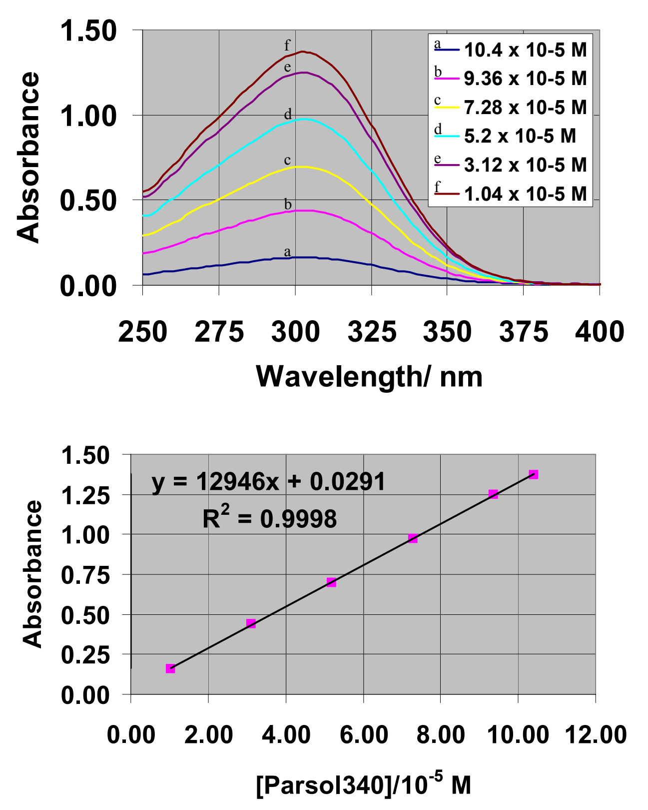

Figure 5: Beer-Lambert law data for Parsol 340 in methanol.

remains constant for extended periods of UV exposure; ie both isomers are effective at absorbing UV and dissipating the energy via photoisomerisation. Parsol 340 does undergo 'photoisomerisation', but of course both 'isomers' are identical and this accounts for the lack of any significant effect on its spectral profile as a result of exposure to UV light. The students learn an important point here – the sunscreen is not 'going off' or 'breaking down'; a photostationary photostable isomer mixture is established and this is what it is designed to do!

Ciba Sunscreen Simulator: Here the students have to register on-line in order to be able to use the simulator. The simulator calculates the sun protections factor (SPF), UVA/UVB ratio and other parameters for a specified formulation of ingredients at specified concentrations. The program returns the spectral absorption and transmission profiles of a model sunscreen film, which the students can relate to the SPF and UVA protection factors, and the results can be saved as a pdf file for inclusion with the laboratory report. At present the students are simply required to formulate their own sunscreen (including at least one of the sunscreens they have studied) and to report the SPF and UVA protection ratings. An example of the output information is given in Figure 7.

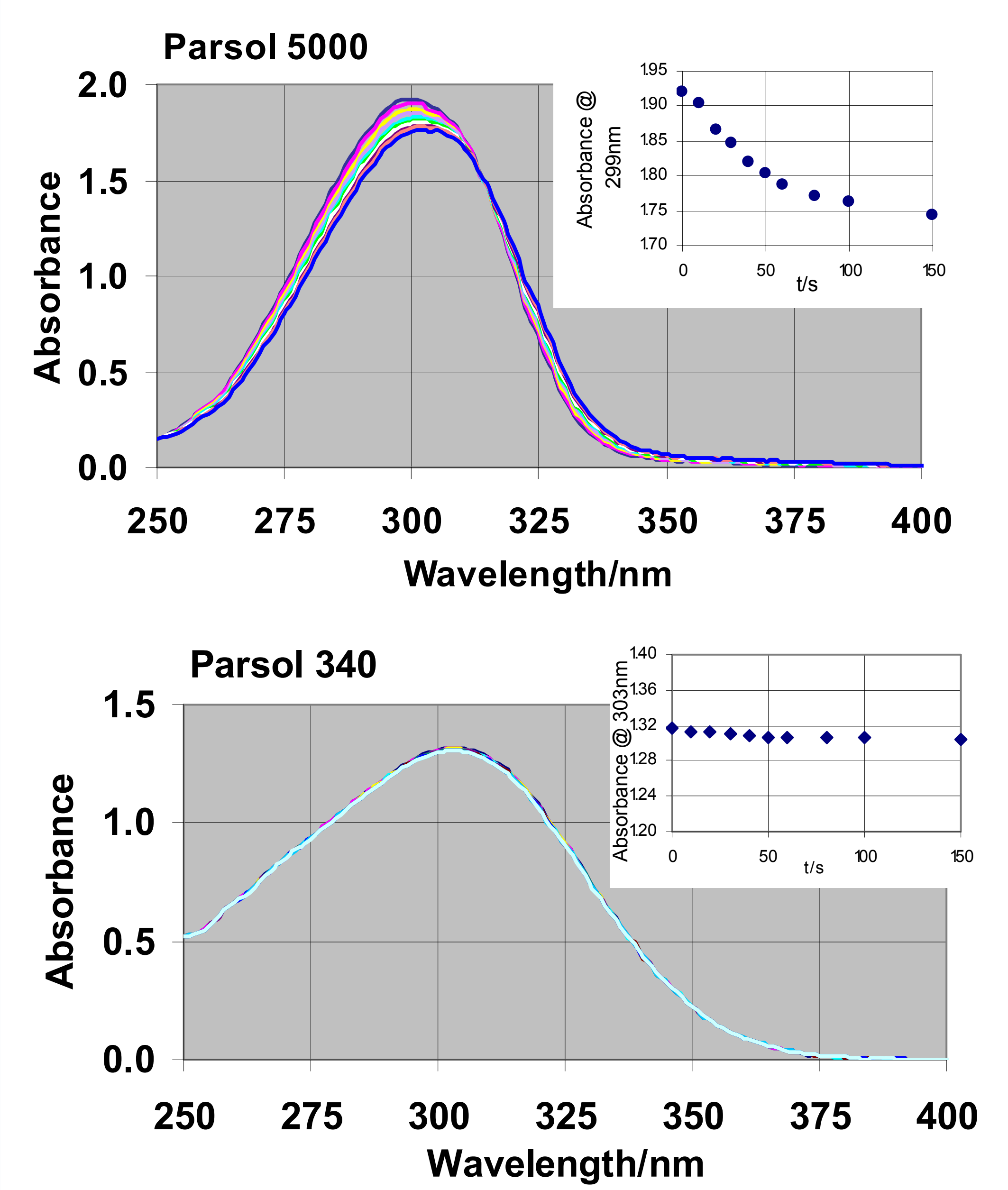

Figure 6: The effects of exposure to 313 nm UV light on the spectral absorption profiles of Parsol 5000 and Parsol 340. For Parsol 5000, the photo-stationary and photostable mixture is established by ~150 s.

- As it dealt with a commercial product, I felt like it wasn't one of those purposeless experiments.
- Useful in future – teamwork.

The following comments were obtained from mature students who did the practical as part of a pre-PGCE subject enhancement course:

- An excellent 'real life' exercise. Good practice of basic lab techniques and reinforcement of practical spectroscopy. Excellent supporting paperwork made it relatively straightforward to carry out and the requirements were well defined.
- Very relevant given the time of year! Lots of interesting data emerged which generated much thought on the issue of sun protection.

Sunscreens: What did you dislike about this practical?

- Too long.
- In a group, some just stand and watch.
- Not sure what I was doing.
- Repetitive.
- Write-up very time consuming.
- Got confused.
- Boring.
- Not enough time to repeat measurements.

Student Feedback

The student feedback on the practical was generally very positive with negative comments largely relating to the workload associated with the practical and the write-up. Representative student comments include:

Sunscreens: What did you like about this practical?

- Learning to use a spectrophotometer.
- Interesting to see the effect of sunscreens.
- Creating my own sunscreen.
- Effects of UVA, UVB interesting.
- Interesting practical.
- Learning how to use autopipettes.
- Interesting and fun to research.
- Interesting to learn about the chemical properties and structures of sunscreens.

Conclusion

From a combination of the student feedback (including anecdotal feedback) and my own observations it is clear that the students generally enjoyed the practical, found it interesting and a good learning experience. In addition, it is evident that the real-life context of the practical was received positively. However, as with the photochromism practical, it is evident that some students feel that the practical is too long and a bit repetitive, and that the write-up is very time-consuming. On reflection, it is evident that the demands of the experimental work and the write-up can be significantly reduced whilst still achieving the desired learning outcomes. Future development of the practical will therefore focus on considered modifications to the design of pre-laboratory and post-laboratory work and a review of the overall information load and student workload.

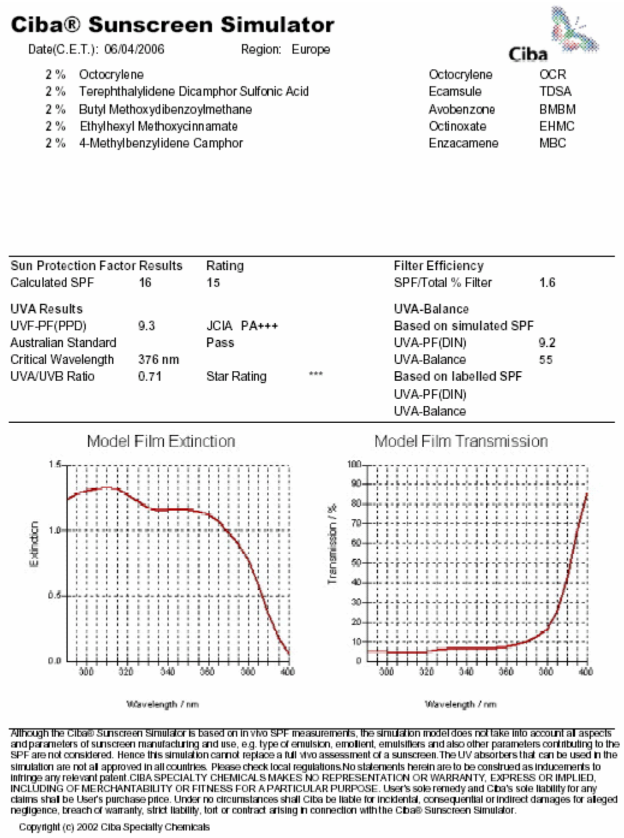

Figure 7: Ciba sunscreen simulator example (https://www.cibasc.com/pccibasunscreensimulator/)

Summary

The use of real-world contexts has the potential to enhance the scope of a practical in terms of what students can learn and do. In this article I have described the principal features of what I have termed industry-linked practicals. The distinctive features of the practicals can be summarised as:

- Core chemistry within tangible industrial/commercial contexts.
- Handling of actual commercial samples.
- Practical activities that mirror those undertaken in industry.
- Information retrieval using on-line resources (pre-lab and/or post-lab).
- Exposure to, and interpretation of, industry-specific data, terminology and jargon.
- Acquisition of experimental data that can be directly (or indirectly) compared with available commercial technical data.
- Learning about the chemistry behind commercial products and some of the key issues for the design and marketing of these products.

The practicals have generally been received positively by students and it is evident that they find the contexts interesting and enjoyable. However, the demands placed on students in terms of acquisition and analysis of data and assimilating information is perhaps excessive and further development of the practicals will aim to address these issues.

In addition, there is more scope within each practical to provide more opportunities for students to apply their knowledge within specific commercial contexts.

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Enterprise Skills for Physics Undergraduates

Abstract
With the support provided by a Physical Sciences Centre Development Project we have developed a self-contained 3-hour seminar activity that explores entrepreneurship and creativity. The seminar is aimed at first year undergraduate physicists. The seminar introduces the concepts of entrepreneurship, has some short warm-up activities and is followed by the main business game. Teams are required to give a presentation of their outcomes at the end. All participants vote on the best proposal. Resources including PowerPoint files and handouts are included in the project resource pack.

The challenge for Physics departments is to prepare the next generation of scientists ...The need is for a proportion of our graduates to be equipped to realise their full potential in the entrepreneurial age.

Background
There are a number of drivers for the inclusion of skills development within undergraduate and postgraduate degree programmes. The Dearing report of the National Committee on Inquiry into Higher Education (1997) contained recommendations on employability and work experience, and encouraging entrepreneurship in HE programmes. More recently the Roberts' Report 'SET for Success - The Supply of People with Science, Technology, Engineering and Maths Skills' (2002) contained recommendations that; "… the training elements of a PhD – particularly training in transferable skills – need to be strengthened considerably". Furthermore that; "HEFCE and the Research Councils … should make all funding related to PhD students conditional on students' training meeting stringent minimum standards". It continued: "In particular, the Review believes that HEIs must encourage PhD projects that test or develop the creativity prized by employers."

Employment is becoming an increasingly important concern for most students. It is known that a student's capability for continued life-long learning is determined largely through University experience. The widening participation agenda has introduced a greater need for skills development in undergraduate programmes. Increasing undergraduate populations have resulted in more competitive recruitment processes with the need for students to make their acquired skills more explicit. Employment statistics reveal that a significant proportion of undergraduates choose a career not related to their subject of study and that 60% of graduates leave their first job in 3 years. Employability is now a central theme of the DfES (The Department for Education and Skills) strategy. The government wishes to see an increase in the skills base in the UK. In the European context the European Union has set itself the goal of becoming the most competitive and dynamic knowledge-based economy in the world by 2010 – the 'Lisbon Strategy'.

The issues of broader skills and employability are challenging traditional views of higher education and its role. There is a growing recognition that, in addition to providing a thorough and rigorous grounding in an academic discipline, universities should also be considering how they equip students with a range of skills to prepare them as life-long learners who will take responsibility for their continued professional development beyond their university education. We now have skills included in level descriptors in the National Qualifications Framework, QAA (Quality Assurance Agency) subject benchmark statements and the QAA Code of practice: Career, Education, Information and Guidance.

A look at developments of the last 10 years shows a decline in large corporate research activity. This has had a significant impact on research overall in the UK with a decline in science and engineering research base. We have seen a substantial increase in spin-off firms created by professional scientists. For many of these the long term success is not guaranteed. Graduates in general are ill-equipped for this type of career path.

To be successful it is accepted that 'skills' should be embedded in academic programmes rather than a bolt on. The students' perception is that they then have the same importance (and assessment weighting!) as more traditional academic work. Effective skills training encourages students towards strategic thinking and reflection, and for many students developing skills requires recognition of how they learn. This process can be reinforced by formative assessment and feedback which have an important role in skills development. Good formative feedback can stimulate a reflective approach to learning and encourage continuous self-assessment of work. There is a growing body of evidence that skills make students better learners. Addressing skills through the curriculum can have a positive impact on the academic and long-term performance of students. In particular skills encourage reflection and articulation, both key elements of successful recruitment.

What are Enterprise Skills?
One definition is: "entrepreneurship is the innovatory process involved in the creation of an economic enterprise based on a new product or service which differs significantly from products or services in the way its production is organised, or in its marketing." (Curran and Burrows[3]). An alternative definition is: "person in effective control of commercial undertaking; one who undertakes a business or enterprise, with a chance of profit or loss; contractor acting as an intermediary." (Oxford Dictionary).
It is interesting to consider the type of entrepreneurial and creative activity that we are trying to develop in our students and compare that with the way in which most of our institutions are managed.

Bureaucratic/Corporate	Entrepreneurial
Order	Untidy
Formality	Informal
Information	Observing
Planning	Intuitive
Corporate Strategy	Tactics
Control Measures	Individuality
Formal Standards	Personally observed
Transparency	Ambiguous
Functional Expertise	Holistic
Systems	Free environment
Performance appraisal	Customer focus
Positional authority	Shared tasks

Table 1: A comparison of the entrepreneurial setting with the corporate setting.

In terms of pedagogic process the outcomes we are seeking are in three broad categories: 1) behaviours (independent, achieving, flexibility, persuasive, commitment); 2) skills (problem solving, creativity, planning, negotiating, decision maker); 3) attributes (confident, autonomous, versatile, dynamic, resourceful).

The challenge for Physics departments is to prepare the next generation of scientists, some of whom will require the kinds of qualities discussed above. The need is for a proportion of our graduates to be equipped to realise their full potential in the entrepreneurial age. This has been part of the rationale behind the 13 Science Enterprise Centres set up across the country.

In an article in Physics World[13], David Auckland the director of the Manchester Science Enterprise Centre writes: "The success of the world's traditional economic powerhouses – Europe, US, Japan – for many years depended on their ability to convert basic raw materials into saleable goods. But as developing nations have learned how to produce high-quality artefacts at competitive prices, the role of manufacturing has declined. Knowledge is the raw material of the modern age and success is determined by how fast it can be converted into new added-value products and services".

In this context we decided at Durham that it would be beneficial to introduce first year undergraduate Physics students to an activity designed to stimulate entrepreneurial thinking.

The Seminar
We developed a 3-hour enterprise skills seminar which includes a 'business game' to stimulate students' entrepreneurial thinking. The seminar was run as a pilot in the academic year 2003/2004 with a small group of first year undergraduates. The seminar was targeted at first year undergraduate physicists with the aim of making them aware of their own enterprise and creative skills. The seminar emphasised the relevance of these skills to the students by presenting case studies based on members of the Department of Physics in Durham.

One of the intended outcomes is that the students recognise the value of entrepreneurial skills in a wider context, and how these may enhance their effectiveness. It also encourages students to engage efficiently with a particular problem or situation in an area where they have no previous experience. This seminar has been specifically designed to be transferable to other contexts.

Feedback from the pilot group of students was extremely positive and through this a number of areas were identified for development. Students particularly liked the topics for group discussion, which highlighted a number of possible careers involving physics.

Building on the work of the pilot, we have developed a revised 3-hour seminar. The resources for this seminar are available as *PowerPoint* files.

The Durham Physics enterprise seminar is structured as follows:

1. A self-contained 3-hour seminar, which can be delivered by a member of academic staff to groups of first year undergraduate students. The nature of the seminar and the resource pack ensures that those delivering the seminar do not require specialist entrepreneurial knowledge. This was repeated for the entire class of 200 students. The seminar was incorporated as an element of our first year 'Discovery Skills in Physics' module. The module is designed primarily for students studying Physics or Natural Science programmes. The module aims are:
    - to provide basic experimental and key skills required by physicists;
    - to provide a structured introduction to laboratory skills development, with particular emphasis on measurement uncertainty and written communication skills;

- to provide students with practice in the application of mathematics to practical problems.

The entrepreneurial seminar was one of a range of activities undertaken by the students during the course of this module. The seminar is not summatively assessed although formative feedback is given.

1. The first 30 minutes of the seminar give an introduction to the concepts of entrepreneurship. The aim is to show that most people behave in an entrepreneurial, or creative, manner without consciously realising it. The students are encouraged to reflect on traits such as creativity, adaptability and broader thinking, which are important in all walks of life. This may also give students possible ideas for the options available to them as physicists at the end of their degree programme. Our introduction includes examples of familiar names: Henry Ford, Richard Branson, Bill Gates, Steve Jobs and Anita Roddick. Others could be included as appropriate. This section concludes with a brief review of successful businesses which have been set up by staff in our own department.

2. The next stage of the seminar presents two short warm-up activities for the teams (4-6 students). Students are given five minutes to come up with a solution to the two questions:
   - Prof. X is annoyed because Durham Cathedral is blocking the view from the office. Your task is to think of as many ways as possible to solve Prof. X's problem.
   - You need to raise a billion pounds by noon tomorrow. How are you going to do this?

   Each team must present their top 5 solutions and everyone votes for their favourite solution.

3. The next two hours of the seminar are activity based. Students, in teams of 4-6, are provided with a pack containing a profile of 'Fermiville'. The pack contains details of demographics, retail outlets and amenities, education, transport and access, local industry, utility infrastructure, cost of living, average salaries and rental properties of this fictional large town. There are proposals for a number of business opportunities. These have a technological flavour to them to reflect physics interest. It would be possible to include other opportunities more pertinent to other subjects. Each venture has a number of positive aspects and a number of flaws (including physical or technological problems). Each group has to choose one of these ventures, which they believe has the potential to succeed and develop a business case for this. The groups are required to devise a short presentation during this period of activity.

4. The final 30 minutes are used for delivering each group's short presentation. The students vote for the best presentation. Time is set aside for open discussion of students' perceptions, and for a questionnaire to be completed.

Feedback has shown that the majority of students engage well with the seminar and are stimulated to consider further their skills in a broader context.

Feedback

We have analysed a range of feedback from a sample of student participants. Students were asked to rate 6 aspects of the seminar from 1 (poor) – 5 (good):

a. How did you find the seminar overall? (**3.6**)
b. Was the introduction clear and informative? (**4.0**)
c. Was the ice-breaker (warm up exercise) useful? (**3.6**)
d. Was the ice-breaker enjoyable? (**4.0**)
e. Were the information packs clear and informative? (**3.8**)
f. Were the business situations described clearly and did they contain enough information? (**3.2**)

The written comments can be summarised as follows:

1. The majority of students regarded the workshop as highly successful and had a high level of engagement with the tasks they were required to do.
2. Many students commented that they enjoyed this seminar more than other (laboratory-based) aspects of the module.
3. A number commented favourably about the seminar involving all students.
4. The most useful elements of the seminar were quoted as:
   - "Learn what things to think about if you were going to set up a business"
   - "More fun than labs"
   - "Get some direction on where to go after graduation"
   - "Widening your thoughts"
   - "The different business ideas show applications of physics degree"
   - "The group interaction"
   - "The seminar on enterprise was good - a refreshing change"
   - "Good to be put in a group and having to work as a team – gave a different perspective. Good to see the more practical aspect of physics"
5. All students who were asked "Would you recommend this to other students?" replied "Yes".

Staff who had helped deliver the seminar were asked: "How well did students engage with the task?" The responses received were:

1. "I was pleasantly surprised how well the students engaged. I can only think of one or two who did not take it seriously. In particular I think the creative thinking exercises are essential to setting the tone for the session. My strategy was to let students form their own groups of ~4 at the start of the session."
2. "I left the room for each of the creative thinking exercises and business planning and just let them get on with it. (I did peek round the door occasionally to make sure they were engaged - they always were.)"
3. "Once they had got some way into the process I would then circulate round the groups, helping (or throwing spanners in the works) as appropriate."
4. "One thing that really surprised me was how good and confident the presentations at the end were. Perhaps this is one positive outcome of Curriculum 2000!"
5. "In most instances the other groups seemed to really enjoy questioning the presenting group on their plans."
6. "As part of the debriefing session at the end I normally asked them what they had got out of the session and what we should change. The responses were always positive - much more fun than a normal lab session. I feel that the whole exercise has worked much better than I originally imagined. We definitely should retain this for the future."

Conclusions

We have developed and successfully piloted a three hour seminar focusing on entrepreneurial skills. Feedback has shown that the majority of students engage well with the seminar and are stimulated to consider further their skills in a broader context. The next stage for Durham is to investigate the possibility of developing an entrepreneurial module.

The concept of this seminar has been shown to work successfully with Physics undergraduates at Durham. A package of materials has been designed which is suitable for delivery by a non-specialist member of staff. The material can be easily adapted for use within other disciplines.

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A Case Study in Green Chemistry: Developing Replacements for CFCs

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The case study has been used in several institutions and has received very positive feedback from both staff and students.

Abstract

Chlorofluorocarbons, CFCs, were developed in the late 1920s for use as safe refrigerant alternatives to sulphur dioxide and ammonia. They were welcomed by industry because of their low toxicity, chemical stability, low flammability, low cost and ease of synthesis. They found wide application as refrigerants, blowing agents, propellants and cleaning agents. Over more than 40 years, applications of CFCs expanded into a wide variety of areas, and grew into a multibillion-dollar industry. Unfortunately, CFCs are not ecologically benign. It became increasingly clear that CFCs were responsible for ozone depletion. In the early 1970s the leading manufacturers of CFCs met to discuss the possible environmental impact of their products.

This case study uses a problem based learning approach to take students through the development of replacements for CFCs from the 1970s to today. They investigate the background to the CFC problem and consider data that leads to the decision to investigate possible replacements. They must select and design replacement molecules (HFCs), devise syntheses and then consider the challenge to develop the replacements in a socio-economic and political framework. They also consider the problems posed by existing CFCs, the 'fridge mountain' and possible disposal and containment alternatives. The case study brings the story up to date with an investigation of the problems now being associated with HFCs and the search for new alternatives.

This activity successfully teaches applied and 'green' chemistry via a real life context. The chemistry encountered is of an applied/industrial nature and is set in a socio-economic context. The influence of political pressures is also brought in when appropriate. Because the activity adopts a problem based approach it is also successful in developing a range of transferable skills, particularly problem solving, teamwork plus verbal and written communication.

Introduction

The Higher Education Funding Council for England (HEFCE) has identified sustainable development as one of its priorites[1]. It encourages Higher Education institutions to embed the principles of sustainable development in their strategies and to "develop curricula, pedagogy and extra-curricular activities that enable students to develop the values, skills and knowledge to contribute to sustainable development". In the context of chemistry curricula this priority leads to the embedding of the principles of green chemistry into programmes. This will lead undergraduates to recognise the importance of the chemical industry in reducing the environmental impact of chemical-based activities by developing alternative technologies.

In addition, employers continue to emphasise the importance of the development of a wide range of subject specific and transferable skills during university courses[2-4]. Various strategies have been developed within the discipline of chemistry for delivering this range of subject-specific and generic skills. Case studies have a long history in many subject areas and their value within chemistry has long been recognised [5-8]. Problem solving case studies lend themselves very effectively to the teaching of green chemistry. Two examples of this approach have previously been published elsewhere[9, 10].

Although the story of the banning of CFCs (chlorofluorocarbons) because of their adverse environmental effects and the development of environmentally benign replacements is well known to people aged over 30, it may be totally new to current undergraduates and the issues of global warming and the ozone hole are certainly still current. Thus the case study is an excellent vehicle for developing their literature searching and other key skills in a chemical context and for giving undergraduates a real understanding of the complex factors involved in successfully developing new products in the chemical industry.

The aims of the case study are to:

- introduce students to green chemistry and environmental issues.
- introduce students to the role of the chemical industry in developing solutions to the problem of CFCs in the environment.
- provide a real life context for learning chemistry.
- encourage students to make links between different areas of the curriculum.
- engage students in open ended problem solving.
- help students appreciate that there is not always a single 'correct' answer to scientific problems.
- develop team working, communication, critical thinking, data interpretation and problem solving skills.

Methodolgy

The students are divided into groups of three to five by the tutor and they work in these groups throughout the case study. We have run this exercise as both 2 x 2 hour and 4 x1 hour sessions, with tasks being carried out between these classroom sessions.

The case study incorporates five phases:

1. *Is There a Problem*?

Each student is given copies of three papers which were printed in Nature in the early 1970s[11-12] and which are crucial to the CFC story. The students must read and critically analyse these papers and decide if CFCs pose an environmental problem (a) at sea level and (b) in the stratosphere. A 200 – 300 word written summary of the key points and conclusions drawn from these articles is submitted. This is written in an accessible style which could be used, for example, as a press release.

Following discussion, the conclusion is reached that CFCs pose no threat at sea level but do pose an environmental problem in the stratosphere by destroying ozone. The environmental chemistry of this is then explored.

> *...employers continue to emphasise the importance of the development of a wide range of subject specific and transferable skills during university courses. Various strategies have been developed within the discipline of chemistry*

2. *Evaluating the Problem*

A task is set to calculate how many tonnes of CFCs would be required to destroy ALL of the ozone in the stratosphere. This requires the student to consider what assumptions have to be made and data needed in order to carry out the calculation. These include : the earth's radius, the height and mass of the atmosphere, the upper and lower heights of the ozone layer above the earth, ozone concentration and how many ozone molecules are destroyed by one chlorine radical. This data yields an approximate result of 13.5 million tonnes of CFCs.

Data is then presented showing CFC production and release from 1931 until 1973. Students then have to predict when the 13.5 million tonnes figure will be reached. Extrapolation of the figures shows that this will occur in the early 1980s. It becomes obvious that CFC production did not continue at the 1970s levels and thus leads nicely into the international agreements on limiting the use of and then banning of CFCs.

3. *Finding Replacements*

Students generate the following generally accepted, key requirements for the replacements:

- Thermodynamic properties as close as possible to the original CFCs.
- Stability.
- Non-flammable.
- Non-toxic.
- No significant change in any other properties pertinent to that application - eg no change in operating pressure for refrigerators.
- Materials compatibility - eg with lubricants in refrigerators.
- Cheap and easy to make.
- Contain no chlorine atoms.

Data on relevant physical and other properties of some CFCs and possible replacements are given and students decide which compounds might be suitable replacements.

4. *Synthesising the Replacements*

Having established that HFCs (hydrofluorocarbons) or HFAs (hydrofluoroalkanes) are the likely replacements and that a whole family of these will be required to cover all the uses of CFCs, attention focuses on the 'front runner', HFA 134a (CF_3CH_2F).

Each group is required to devise and evaluate synthetic routes for HFA 134a. These are then presented to and discussed with the whole student cohort. The consequences of choosing particular routes are discussed and comparisons drawn with the relatively simple synthesis of CFCs– engineering, technology, environment, catalysts, cost etc.

5. Is the Problem Solved?

At this point students view the CFC problem as being 'solved'. Their attention is drawn to the CFCs already in existence and consideration of containment or disposal or reuse are all addressed as well as the issue of the growing 'fridge mountain' which has been an issue raised in the media[13]. In order to address this latter point each group is given a specific designation, such as Greenpeace, Hotpoint, Du Pont or Liverhull Recycling Company and is required to present proposals for dealing with the 'fridge mountain' from their perspective. They have to include proposals as to who bears the responsibility for this problem and which parties should pay for disposal of old domestic fridges and air conditioning units.

Assessment

The assessment is based on written reports, oral presentations and peer assessment of students contribution to the group work. A proposed assessment scheme is shown:

a.	Literature search and report	20 %
b.	Data interpretation and presentation	30 %
c.	Final presentation and debate	30 %
d.	Peer evaluation	20 %.

Discussion

The case study has been used in several institutions and has received very positive feedback from both staff and students. Students were asked to rate each of the following on a scale of 1 to 5 (where 5 is very highly rated), with the results shown.

"Do you feel that you have developed any of the following skills through studying this case study" ?

solving unfamiliar problems	3.8
working with others	4.0
thinking critically	4.0
communicating your ideas	3.9
link between theory and practice	3.7

Conclusions

This case study has proved popular with chemistry students and has been successful in its aim of developing an awareness of green chemistry. The importance of developing new products to replace environmentally unacceptable ones and turning what could have been a business disaster into an opportunity and success are important lessons to be learned. It has provided some insight into the wide range of chemistry involved in producing new products in the chemical industry and the range of additional factors, such as economics, engineering and even political ones, which can have a crucial influence on the success of the project. In addition, undergraduate students are provided with an opportunity to develop a range of key skills within a chemistry context and the final part of the case study imparted another important scientific lesson - that there is not always a single 'correct' answer.

A copy of the case study with handouts and a tutor's guide is available from the authors.

The importance of developing new products to replace environmentally unacceptable ones and turning what could have been a business disaster into an opportunity and success are important lessons to be learned.

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Formative Assessment in Science Teaching

Abstract
The Formative Assessment in Science project was funded by HEFCE as part of the Fund for the Development of Teaching and Learning Programme. Its work was completed in March 2006. The project was centred on a strong collaboration between the Open University and Sheffield Hallam University, but also involved ~20 other universities in action learning activities aimed at improving formative assessment. The project partners used a conceptually and empirically based framework of conditions which, if met, lead to assessment that drives learning. The projects were diverse and the many positive assessment changes achieved demonstrate that the approach of a framework based analysis and careful evaluation can be successful in improving the student experience. I will summarise some of the main conclusions of the project. One concerns the creation of written feedback that promotes learning rather than merely justifying marks. A second covers the effective use of peer assessment. Finally, I will outline the tools that the project has generated. These will remain available for others to undertake similar reform activities.

Introduction
The Formative Assessment in Science Teaching (FAST) project was funded by HEFCE via the Fund for the Development of Teaching and Learning (FDTL). The project, which formally ended in summer 2006, was concerned with the way assessment affects student learning. It was not about measuring learning but about supporting learning. The key feature of FAST was the combination of a strong conceptual analysis and a very practical and 'down-to-earth' engagement with the reality of teaching and learning. FAST's work is documented in a Web based report that will appear in autumn 2006 and in many publications.

The project has demonstrated repeatedly the value of a process of self-audit of teaching practice within a theoretically and empirically valid framework

The FAST approach to improving assessment relied on a conceptual framework of eleven conditions under which assessment supports learning[1]. These conditions were drafted using a combination of theoretical arguments and observations of effective practice. They highlight the importance of student engagement and feedback. (see Table 1).

Armed with this framework, the project adopted an action research approach. We worked with nearly 30 project leaders who had responsibility for teaching specific science modules. In each case, the project leader analysed the way they assess the module against the criteria for the assessment to support learning, and identified possible beneficial changes. In many cases, they implemented and evaluated the effects of these changes, thus closing the quality improvement circle. This process was aided by using investigative tools developed by FAST, including:

- an Assessment Experience Questionnaire that generates information about student perceptions of assessment,
- a Perceptions of Feedback Questionnaire,
- a Written Feedback Coding Tool that helps the teacher to identify the sort of feedback that is being given,
- a number of structured interview templates.

All of these tools have been used in several projects and are available on the present website at www.open.ac.uk/science/fdtl/.

Engagement	Feedback
1. Assessed tasks capture sufficient student time and effort. 2. These tasks distribute student effort evenly across topics and weeks. 3. These tasks engage students in productive learning activity. 4. Assessment communicates clear and high expectations to students.	5. Sufficient feedback is provided, both often enough and in enough detail. 6. The feedback is provided quickly enough to be useful to students. 7. Feedback focuses on learning rather than on marks or the students themselves. 8. Feedback is linked to the purpose of the assignment and to criteria. 9. Feedback is understandable to students, given their sophistication. 10. Feedback is received by students and attended to. 11. Feedback is acted upon by students to improve their work or their learning.

Table 1: The importance of student engagement and feedback

The project was led by the Open University and Sheffield Hallam University, who together pursued 18 individual assessment improvement projects. A further 15 projects were led by colleagues within partner universities, including Abertay Dundee, Bath, Birkbeck, Brunel, Durham, East Anglia, Hull, Keele, Liverpool John Moores, Napier, Surrey and Wolverhampton. The details of these projects are available on the Website. The titles in the Appendix indicate the scope of the projects.

Given the scale of the work supported by FAST, it is not possible to offer a comprehensive account of what we have learnt. Here is my personal set of issues that have made me stop and think (with reference to the criteria and conditions listed in Table 1).

Self-audit works
The project has demonstrated repeatedly the value of a process of self-audit of teaching practice within a theoretically and empirically valid framework. Even the most experienced teacher can pursue a strategy that is well executed but misguided. For example, my own institution is very fortunate in having a large group of Associate Lecturers who mark and provide feedback on written assignments. The quality of this feedback is widely recognised. However, its value is hugely diminished if we don't set assignments that allow the student to respond to the feedback (Condition 11) and if the feedback is late in arriving (Condition 6). Too often this has been the case.

Many other examples of such blindness have been uncovered by the FAST projects.

Students must understand the guidance we offer
In spite of the introduction of specific learning outcomes and a great deal of energy expended in drafting feedback, there are many examples of students not understanding what we are saying (Condition 9) because of the use of what is in effect jargon. For example, what would a student understand by 'More critical analysis' or '59/100 - excellent'?

A number of teachers have had a great deal of success in improving learning by scheduling sessions for explicit discussion about what is expected of students. This tactic has been a feature of the sister FDTL project, Effective Feedback Enhanced Learning, led by Nottingham Trent University.

Feedback must feed forward
Too often, we draft feedback that is aimed at justifying the marks we have awarded rather than guiding future learning. In many cases too, we focus on content rather than skills. The result tends to be that feedback is valued but is not valuable in that it is not acted upon. There are many tactics that can be used to overcome this. We can learn how to focus the feedback and make it feedforward. We can decouple marks and feedback (Condition 7) so that the student must attend to the feedback in order to evaluate their success. Perhaps most crucially, we can prepare assessment tasks that scaffold learning with the feedback from one task feeding into future tasks.

Self and peer assessment are under-used
Perhaps the most striking gains have been achieved by teachers who have introduced robust mechanisms for self and peer assessment. The latter is particularly interesting. Peer assessment requires students to think about the performance criteria and, through their grading of their peer's work, to focus again on the material covered (Criteria 3 and 4). Very pertinently, it allows students to receive additional feedback without the teacher having to do more work or, where it substitutes for teacher marking, less work. Although peer assessment is by no means new, it is controversial with both students and staff. Some students object and assert that the marking will be inaccurate and that 'marking is your job'. Such objections can be dealt with by introducing it carefully with a fully explained rationale and by including appeal mechanisms. A useful introduction to self and peer assessment has been published by the Higher Education Academy Centre for Biosciences[2].

Computer based assessment has great potential
Although computer based assessment (CBA) is widely used, recent technological advances and increased pedagogical skills suggest substantial further opportunities in both summative and formative roles. Several FAST projects demonstrate that CBA can be used to diagnose areas of need and to check on progress. In these roles, the flexible availability of CBA (Criterion 2) and the promptness of feedback (Condition 6) are highly relevant. In several cases, the CBA reported by the FAST projects is traditional in style with a heavy reliance on multiple choice questions and a concentration on testing knowledge and understanding. However, other projects involve CBA of greater complexity. One of the most interesting developments is the incorporation of tasks that require the student to construct knowledge, eg build a set of apparatus or a molecule. In this way, assessment and learning are connected. A further area of interest is the generation of tailored feedback, again demonstrated in some FAST projects. The key to unlocking the potential of CBA may well lie in the construction of useful and available item banks. Recent Higher Education Academy Physical Science Centre initiatives aimed at filling this gap.

The above list reflects my personal judgements on FAST activities. Developments are continuing. There are several ongoing projects and initiatives that are aimed at improving the effectiveness of formative assessment, eg the Centre for Open Learning of Maths, Science, Computing and Technology, the Centre for Excellence in Assessment for Learning and the Scottish Funding Council initiative, Re-engineering Assessment Practices in Scottish Higher Education.

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Appendix
The following list includes those FAST projects that are complete and documented. Other projects are complete but the reports are not yet agreed. The list is split loosely into four groups that are concerned with; the nature and mode of feedback, the impact of course structures, progress checks, and the use of computers. The placing of the projects within these categories is somewhat arbitrary as several involve multiple interventions and aspirations.

- Removing the grade from a formative assessment.
- Reformatting feedback on assignments to enhance effectiveness.
- Towards an optimised feedback scheme in the teaching of second year physical chemistry to Forensic and Analytical and Pharmaceutical Science students.
- An investigation to find if articulating learning outcomes explicitly changes the nature of tutor feedback comments on assignments.
- Feedback that feeds forward.
- Early feedback to students as they complete assignments.
- Returning formative feedback: traditional versus electronic approaches.
- The timeliness and relevance of feedback to students in a DNA Technology module.
- Perceptions of Formative Assessment in a Fourth Year Project Module.
- A study using formative assessment feedback in physiology and pharmacology to encourage engagement.

- Using assessment within course structure to drive student engagement with the learning process.
- Improving feedback in a level 5 Pathology module.
- A scenario-based approach to Analytical Science with rapid feedback on progress.
- Driving formative assessment through summative means.
- The effect on student learning of replacing assessment of a topic by formal written examination with a continuously assessed problem assignment.
- In-Course Assessment of undergraduate chemistry using 'seen' class tests.

- Millstones or Milestones?
- Supporting Transition.
- Spot checks in Chemistry.

- A Study into the use of computer aided assessment to enhance formative assessment during the early stages of undergraduate chemistry courses.
- A short course assessment strategy with formative impact.
- The formative effectiveness of an online practice assessment.
- Automated Assessed Tutoring.
- Automated Assessed Tutoring – Financial derivatives.
- Assessing the effectiveness of feedback in online objective tests in Mechanics.
- Evaluating the effects of frequent computer-based assessment on the study habits of mature, part-time students in biology.

Development of an open-learning module in natural product chemistry

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Abstract
This article describes the author's personal perspective on the design, production and delivery of an open-learning module in natural product chemistry. This 10 credit, level 6 module is delivered using three tutorial sessions and is assessed by three open-book tests. The study material is available to the students as both hard-copy and electronic copy.

Introduction
The School of Applied Sciences, Northumbria University has a long tradition in providing part-time day release courses at both HNC and BSc levels, and offering Sandwich placements to full-time students. As a former Polytechnic, there has always been this strong vocational aspect to the School's chemistry-based courses.

In 1998, the School was considering introducing an MChem course, possibly with a sandwich element. Part of the sandwich year would have required the student to study a number of modules while on placement and consequently the author began to consider writing a suitable 'distance learning' module. An additional reason for producing such a module was that it might also become available for part-time BSc students. Students attend the School's part-time BSc course one day plus evening per week. The distance a student lives from the University often dictates whether attendance on the part-time BSc course is viable. If the amount of time spent at the University were to be reduced through the provision of some distance learning modules, then this might make the part-time BSc degree more attractive to students who have long distances to travel and also to many of our part-time students who have family and other commitments.

The School's external examiners have also commented favourably on the style and delivery of this module

Although it began as a distance learning module, once the unit had been written it was apparent that it could also be used by full-time BSc students. Thus, the final product is best described as an open-learning module.

One of the problems associated with writing distance or open-learning modules is finding the time to produce the material. Fortunately, development project funding was provided through 'Project Improve' (whose work is now continued through the Higher Education Academy Physical Sciences Centre)[1].

Considerations in module design
The author wished to produce a module suitable for study by final year undergraduate students. Natural product chemistry was chosen for the subject matter because:

- It could be used to reinforce the basic organic chemistry taught in the first and second years of the degree course, principally carbanion chemistry, carbo-cation chemistry, free-radical chemistry, alkylations, oxidations, reductions. Thus, students would be able to apply their existing knowledge, understanding and skills in organic chemistry to new situations.
- It would introduce the student to the biosynthetic principles used by nature to produce a range of natural products and hence students would be able to appreciate organic chemistry in a wider context.
- The module could be extended in the future to cover additional areas of natural product chemistry eg NMR spectroscopy for elucidation of biosynthetic pathways, methods used for the isolation of natural products, the medicinal chemistry associated with natural products etc – subject areas that are not at present covered by the module.
- The module might be extended in the future to cover some additional areas either at the same level to produce a double module, or at a higher eg MSc level to produce a follow-on module.

- The module would be useful to other Universities. Part of the conditions for 'Project Improve' funding was to make the material produced freely available. Other Universities could choose whether to use the module as it stands, supplement it with additional areas, expand existing areas etc.

In writing the unit, the author consulted and used as far as possible the excellent article on designing independent learning material by Dr Stuart Bennett[2].

Module structure
The module was written in five chapters[3]. These were:
Chapter A. Acetyl coenzyme A: a key biological intermediate
Chapter B. Biosynthesis of fatty acids
Chapter C. Biosynthesis of polyketides
Chapter D. Shikimic acid pathway and alkaloid biosynthesis
Chapter E. Terpenes

At the beginning of each chapter there are a list of objectives (learning outcomes) that the student is expected to achieve. There is also an indication of the prior learning a student will need to have in order to appreciate and understand the principles that are being introduced. All chapters have been broken down into of a number of relatively short sections to facilitate digestion of the material. Problems, with solutions, are included at regular intervals to enable the student to test understanding and to provide formative self-assessment. The underlying chemical principles in each chapter are related to familiar organic chemical reactions wherever possible in order to demonstrate the common underlying principles between biosynthesis and organic chemistry. Each chapter concludes with a summary of key points and a further reading list.

The comments and suggestions received from colleagues on the first draft resulted in minor alterations in the final version. The hard-copy was then transformed by the author into a web-site to enable ready access to the material by other Institutions. The hard-copy version and the web-site have identical content.

In retrospect, the module would probably best have been titled 'Natural Product Biosynthesis' but the broader name 'Natural Product Chemistry' has been retained to allow for further expansion of the work.

Delivery of the module
The Natural Product Chemistry module has been running at Northumbria since 1998. It is used predominantly as a semester long optional module (10 level 6 credits) for the School's full and part-time final year degree students and is therefore best described as an open-learning module because the students are in attendance. Typical group sizes are 10-15 students. It has however also been used on several occasions as a true distance learning module for part-time students who have moved away from the region, generally through work commitments.

At the start of the module there is a short introductory session in which the students receive a hard-copy booklet and the organisation and assessment strategy of the module is explained. The module is delivered through three, one-hour tutorial sessions. The students are given a number of problems in advance of each tutorial session and they are expected to attempt these before they attend the tutorial (see appendix A). These problems also allow the students to engage in formative assessment. The first tutorial covers material from chapter A, the second tutorial covers material from chapters B and C and the third tutorial covers work from chapters D and E. During the tutorial sessions, students are expected to explain their solutions to the problems to their peers and thus actively engage with the work rather than passively receive solutions to problems. The tutor also summarises the key principles introduced in each chapter during the tutorial sessions and will also answer any questions.

Assessment of the module
The module is assessed by three one-hour open-book tests (see appendix B) corresponding to the tutorial division. Each open-book test consists of six short questions and takes place the week after the corresponding tutorial. The average mark for the module is generally in the high 50s – low 60s ie comparable with other optional modules that have formal end examinations. In cases where part-time students have been unable to attend the tests, the tests have been e-mailed or sent as hard-copy to employers who have invigilated the test and then returned the scripts.

Student Feedback
Feedback from the module has been extremely positive. Students have commented that they can work at their own pace and the module is much more flexible than traditionally taught modules. They also like the tutorial style and the use of open-book tests as summative assessments. Many full-time students have commented that because of substantial part-time work commitments, open-learning has enabled them to manage their time more flexibly. Part-time students who study day and evening have commented that open-learning is a welcome break from the traditional routine of lectures and laboratories throughout the day.

Summary
Preparing the material for the Natural Product Chemistry open-learning module was time intensive but the rewards have been excellent. It has made students responsible for their own learning and has enabled some students to complete the module successfully without attendance at the University. The tutorial style of delivery and assessment by open-book tests has proved tremendously popular with the tutor and the students. The School's external examiners have also commented favourably on the style and delivery of this module. I hope colleagues at other Institutions are able to make use of this resource.

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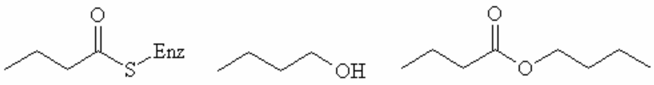
Acknowledgements
The author would like to thank 'Project Improve' for funding the development of this module and colleagues who have provided useful feedback and suggestions on the module's design and content.

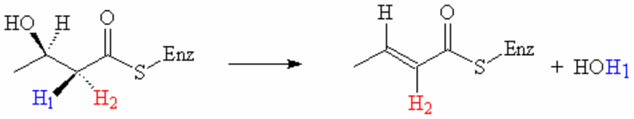
Appendix A
An example of a set of tutorial questions. The questions below relate to Chapter A.

Tutorial 1

1. If labelled acetate $^{*}CH_3CO_2^-$ (* = ^{14}C) was used in the biosynthesis of stearic acid, at which positions would you expect the labelled carbon atoms to appear ?
2. You are unsure whether the methyl group in tuberculostearic acid is derived from propionate or *S*-adenoyl methionine. Suggest a suitable labelling experiment which might resolve this.
3. Thioesters **1** can be reduced to alcohols **2** by NADH. Write a mechanism for this reduction. Show how the ester **3** might therefore be biosynthesized from appropriate thioester and alcohol precursors.
4. The stereochemistry of the elimination of water from thioester **4** giving the alkene **5** is shown below. Is the elimination of water a *syn* or *anti* elimination ?



1 2 3



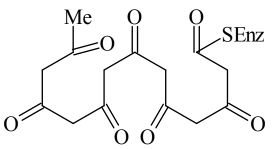
4 5

Appendix B
An example of a set of open-book questions. These questions relate to Chapters B and C (polyketides and shikimic acid).

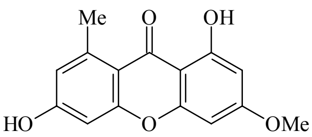
CH335 Natural Product Chemistry
Module Open Book Test Number 2

Name:
Grade: A B C D E F

Time allowed: 1 hour.
Answer all questions (all questions 5 marks; 30 marks in total - a preliminary grade will be awarded. Marks may be subject to moderation by the examination board)

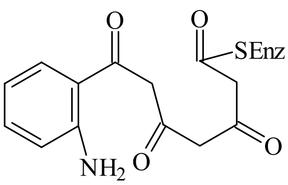


1

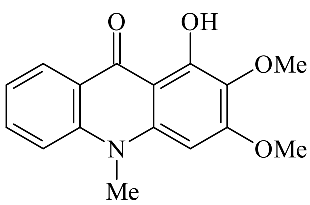


2

1. Propose a reasonable biosynthesis of Grieseoxanthone C **2** from the polyketide **1**.



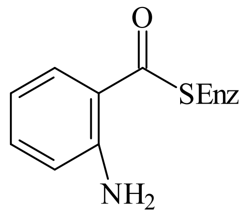
3



4

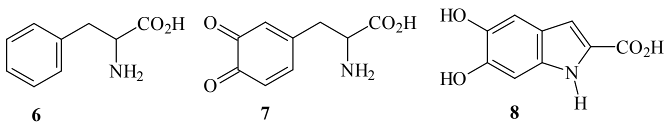
2. Show how the polyketide **3** might be converted into Aborinine **4**.

3. Show how polyketide **3** might have been biosynthesised from the starter unit **5**.



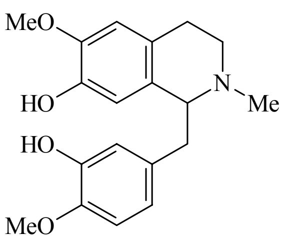
5

4. Compound **7** is an intermediate in the biosynthesis of the indole derivative **8** from phenylalanine **6**. Propose a reasonable biosynthesis of compound **7** from phenylalanine **6**.

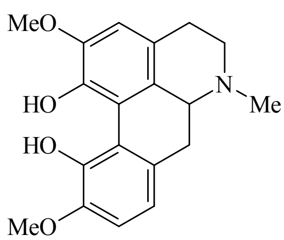


6 7 8

5. Show how Reticuline **9** might be converted into Coryuberine **10** *via* phenoxy radical intermediates.



9



10

6. If labelled acetate, where the label is on the methyl carbon atom, was used in the biosynthesis of compounds **2** and **4**, indicate on structures **2** and **4** (with an *) the positions at which you would expect to find the labels.

Project LeAP: Learning in Astronomy and Physics

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Abstract

The aim of the project was to raise awareness of problem-based learning (PBL) in physics through the development of exemplars relevant to the HE context in the UK, and through road shows and seminars on the background to PBL. There is also a LeAP web site devoted to Physics PBL. The project was carried out in collaboration with partners in Hertfordshire, Reading and Sheffield and the results published by the Physical Sciences Subject Centre as a practice guide to PBL in Physical Sciences. This article will discuss some of the evidence gathered by the project on PBL in physics worldwide, and report on some of the implementations that are beginning supported by the project as well as future developments in the Physics Innovations Centre for Excellence.

Introduction

Tradition is a limitless resource. It can be used endlessly to defend why everything is as it is and not otherwise. And indeed, if things have worked in the past why should they not work now? Tradition is particularly strong in a subject like physics: Newton's laws have not changed for three hundred years, Maxwell's for one hundred and fifty and Einstein's for a hundred (give or take, here and there). The current way we express these and other laws, and the way we understand these branches of physics, has been taught to generations of physics students – with obvious success, since physics has not died out (yet). So why change the way we teach?

Where to begin! The subject content may have stayed the same but the learning environment has changed. The traditional specification of the physics curriculum is manifestly uninspiring to the majority of students, who are led to believe that physics is a set of arbitrary lists of equations in areas such as heat, light, sound, gravity, … that are disconnected with each other and with anything meaningful in 'real life'. A magnifying glass may well once have competed with a flower press for a child's attention, but it does not appear to enthrall the videogames generation.

It is also tradition that physics presents a long and arduous learning curve that has to be climbed by means of apparently endless end-of-chapter exercises, of no intrinsic interest, in order to get to the really interesting stuff. But this interesting stuff is located somewhere at the end of a rainbow for most students, who don't in fact ever get to *[address] profound questions about the universe [or]… understand the complex physical and environmental systems in which we exist*[1].

It is a traditional claim that physics is a linear subject that requires mastery of the fundamentals before moving on. This would not be worth contesting were it not for the fact that curriculum designers and lecturers appear to use this fundamentalism to justify the boring bits. In fact, the linearity is much over-hyped. One is rarely building on firm foundations: the understanding of most students is partial and inaccurate and only deepens through repeated exposure in different contexts. And it seems to have been forgotten that 40 years ago at least one A-level physics syllabus contained no mechanics: it is indeed possible to start with light, or heat or… . Of course, this approach loses the logical structure of physics, but it is a mistake to try to impress that structure on students who lack experience beyond that of the early undergraduate years. In other words, to my mind the logical structure of physics only appears logical in hindsight.

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And finally, as a discipline, we keep repeating the mantra that physics is interesting to anyone who cares to think about it. I'm not sure about this: I think what physicists find interesting is being physicists doing physics, not taking notes on what they are being told.

Seen from many of our ‘traditional’ institutions the declining popularity of physics is a bit of an illusion. Measured purely in terms of numbers of undergraduates many Departments have apparently never been healthier. It is however a real problem for the UK as a whole. So we must DO something!

So what about making it fun! I have no evidence beyond introspection to back this up, but I think that is a really BIG mistake. My own view is that we need to render physics more serious. By this I mean that we illuminate the way in which the study of science, and of physics in particular, can offer a real opportunity to contribute to making a difference to the world. For, if physics is just a matter of individual gratification, why on earth is it important? I do not mean to equate ‘serious’ with ‘dull’ – physics can (should) be as much fun as you like, provided it is manifestly serious. An obvious example is medicine, the value of which is clear. It is this message that we need to substantiate.

How? Well my own favoured candidate is through problem-based learning (PBL) and it is this that the FDTL4 project LeAP was supported to develop. It is certainly exciting to study outer space, but a student cannot do very much with the knowledge. I think Ohm’s law should be even more exciting, because armed with an understanding of this, one can build a circuit to do things that no-one else in the history of the world has ever done before (if you will forgive a little bit of exaggeration to make the point). PBL poses a problem as a focus for student engagement, preferably a problem that is meaningful for students with their current experience, and exploits the benefits of collaborative learning by requiring students to work in groups. In this way it answers many of the difficulties of the traditional approach. It is student-centred, asking students to operate as physicists throughout, and starting from where they are with their own learning issues. It is capable of supporting multiple endpoints depending on student interests and abilities. It can underpin curricula of various shapes, by area of physics (if you insist) or by themes. And above all it shows that knowledge is important because of what you are able to do with it.

To develop these themes, in the course of project LeAP we ran various roadshows in Physics Departments across the country. We were able also to develop PBL in Leicester physics from a nascent concept through to a fully-fledged implementation across all years, although not across the board and not where other approaches are more efficient. We were also able to develop a new degree programme in Interdisciplinary Science taught wholly through PBL, funded in part through FDTL4. Outside Leicester we were able to assist in the implementation of PBL in physics at Dublin City University, Dundalk Institute of Technology, The Universities of St Andrews, Bath, and Thames Valley as well as in Science Foundation Degrees in Newman College, Birmingham and Wyggyston QE College, Leicester. In addition our survey showed that up to half of the Departments of Physics claimed to have some PBL in their curricula. We also spread (and received) the message at various international meetings in Korea, Finland, Mexico, Peru and the US.

It was never part of the project to take PBL into schools, although in the US it is at this level that PBL in Physics has perhaps made most progress. It was interesting though to get the reaction of at least some physics teachers at Institute of Physics meetings, where it was claimed that any variations from teaching-to-the-test in schools would be impossible because of the focus on league tables!

One of the most important aspects of a project is a legacy. Project LeAP was unusual for an FDTL project in that it did not have as an objective the production of teaching materials in a form for others to use. What then is the legacy of project LeAP? Our annual International Summer Workshop on PBL, now in its fifth year, will be continuing, under the umbrella of the πCETL (the Physics Innovations Centre for Excellence in Teaching and Learning). There is a guide to PBL published by the Physical Sciences Subject Centre and available through their web site that offers practical guidance to anyone thinking of adopting PBL. This highlights the many approaches to PBL across the world, but also offers advice from experience of how things can go wrong. The LeAP web site itself[2] hosts a bank of problems that will continue to grow in number. And, again continuing as part of the πCETL, we are happy to share our experiences with anyone who thinks they might benefit from them. One project is of course not going to change the nature of physics teaching, certainly not over three years, but it can contribute to a momentum for change that will ensure the healthy survival of the discipline and, perhaps, a new tradition.

I am grateful to Dr Sarah Symons who managed the project wonderfully well, sometimes despite me. We are both grateful to our colleagues for their contributions to project LeAP, particularly our project partners Jim Collett at Hertfordshire, John McDonald at Reading and Craig Buttar and David Mowbray at Sheffield, the many assistants too numerous to mention individually who toiled to develop PBL materials and the staff at Leicester who helped to implement them. We enjoyed the unstinting support of the Physical Sciences Subject Centre and the Institute of Physics.

Project LeAP is supported by the Fund for the Development of Teaching and Learning (FDTL4)

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From Projects to Problems

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Abstract
Projects are a familiar feature of physics curricula and many courses include one or more group projects as a way of developing group work skills, if not for teaching physics. Problem-based learning on the other hand, which is designed primarily to teach physics while enhancing group work skills, is not so familiar. In this article we shall show how project work can be developed rather simply into problem-based learning by contextualising the project in terms of a problem and a viewpoint. The examples given will be based on developments of first and second year courses at Leicester to integrate practical, computational and theoretical work within the programme of specialist options. The benefits to staff and students will be discussed.

Introduction
Final year projects are now such an established part of the undergraduate curriculum that it is difficult to appreciate that when I started as a lecturer in physics they were, as I recall, a recent innovation in a few pioneering Departments. Group projects on the other hand, while widespread, are not universal in physics curricula, and even when they are present they are often considered as peripheral. Indeed, their justification is often expressed in terms of the development of group skills and team work rather than the teaching of physics content. This paper describes the history of our recent development of group projects at Leicester to support teaching of specialised options. A particular feature of these projects is the integration of practical and theory. The result might be described as the introduction of problem-based learning through the back door, as it were. The comparison with the core component of problem-based learning (the approach through the front door so to speak) has been instructive.

change needs a strong motivation and the promise that it will lead to greater efficiency once implemented

Background
In problem-based learning (PBL) students start from a problem or puzzle and, working in groups, seek out the new knowledge they need to solve the problem. A good PBL problem or puzzle is usually described as ‘real world’, but the essential point is that it should be expressed in such a way as to engage students, which often, but not always, means that it should relate to ‘real life’ (in this context meaning as experienced by physicists in their work). In[1] Savin-Baden offers a number of distinctions between PBL problems and projects, not all entirely convincing. The main difference for our purposes is that projects are used to introduce open-ended research in a novel context, probably not duplicated from year to year and probably not conducted as a group exercise. PBL on the other hand, as it is usually implemented, has specific content objectives within the agreed curriculum.

The distinction is not a sharp one. Our own ‘rocket project’ for example[2] illustrates to some extent the overlap. There is a given problem, in this case to build a rocket to launch a payload that will obtain scientific data which can be recovered and analysed. (A simple example might be to measure the vertical variation of the Earth’s magnetic field at the launch site.) The students work in pairs on different aspects of the problem (design, electronics, data analysis and so on), so this is not PBL; on the other hand a subset at least of the core learning outcomes are common from year to year, the investigation is not essentially novel, and the students have to work as a group to fit the different aspects together, so this is not a standard final year project and bears many of the hallmarks of PBL.

A key feature of the rocket project, shared by good PBL problems and final year projects, is that it generates a lot of student enthusiasm and engagement. The question then arises as to whether the lessons of the rocket project can be applied to core learning. For our immediate purpose we identify the 'core' as the compulsory components of our various specialist degree streams (we call them physics 'flavours') of physics with astrophysics, space science, nanoscience, planetary science and plain 'vanilla' physics.

Why change?
Change is expensive, and although some new lecturers may get a lighter teaching load to set up their courses, beyond that it is never entirely clear where the resources for teaching developments are supposed to come from. Thus, change needs a strong motivation and the promise that it will lead to greater efficiency once implemented (usually meaning less staff resources rather than better student results, but at least consistent with not significantly enlarged resources and no less a student experience). So what were the motivators?

1. The effectiveness of the standard laboratory in fostering the development of physical understanding has often been questioned and various alterations have been proposed to address this (eg Johnstone et al[3]). For example, our students who have followed the laboratory script to construct their own numerical stellar models, still find difficulty in answering examination problems on stellar structure.
2. Conversely, one might query the effectiveness of lectures in conveying information about practical aspects of a subject.
3. Practical work, whatever the benefits of the previous regime, had become a chore for staff and not very exciting for most (not all!) students. The laboratory experiments were tired and needed renewal, but there was little enthusiasm for doing this.

In introducing elements of PBL to combine some of the laboratory work with the presentation of theory, we had in mind that it would enable students to experience being, say, an astrophysicist (at some level), not just learning about astrophysics, in much the same way that our rocket project enables students to experience being a rocket scientist, not just to hear about how it is done.

The student viewpoint is difficult to disentangle, partly because they have not experienced the experiments and lecture courses that have been replaced.

Some example projects
To give a flavour of the projects I will outline a few examples (*The intention is that further details should be available on the web in due course through the πCETL and the project LeAP problem bank, www.le.ac.uk/leap*).

1. Observational astronomy, year 1

This project involves the construction of a telescope, by students working in pairs, from some supplied lenses, a digital camera, computer and software and a cardboard tube which can be cut to a length of their choice. Students must characterise the optical properties of their telescope (resolving power, chromatic aberration, calibration using standard *simulated* stars and so on), which cannot be obtained by asking the laboratory demonstrators (or their colleagues) since the configuration is unique to the particular pair of students. Students then observe a *simulated* variable star system. This is a binary system with a period of 6 hours, much longer than the length of the laboratory session. A number of pairs of students (from different sessions) must then exchange information to determine the properties of the binary system. They can only do this effectively if the calibrations of their telescopes are correct. Thus, there is no prior known right answer to this, but students have to get the answer right to solve the problem. (And, incidentally, understand the sources of error and evaluate them correctly!)

2. Nanoparticles, year 1

This project involves a novel way of making nanoparticles of sodium chloride by thermal evaporation of a spray of salt solution. Students have to set up the experiment, including a calculation of the appropriate concentration of solute, and attempt to characterise the particles by optical absorption. They also get to look at the nanoparticles in an atomic microscope to confirm their estimates.

3. Stereo-Imager, year 2

Students are asked to design, build and test a (small scale) stereoscopic imaging device for a planetary rover that can be used to estimate distances and to project green/red stereo images.

Each of the projects requires students to seek out the relevant theory and put it into practice. Some of the projects integrate an element of computation also.

Development
The projects were developed largely by recent graduates working over the summer period under the supervision of the responsible academic member of staff with a variable degree of interference from myself, mainly to try to guide the projects away from a reinvention of the standard scripted laboratory practical and towards a problem to be solved with the necessary support materials (and to sign the requests for just another few (hundred) pounds of equipment).

Structure
Both years are run in the same way. Each laboratory session (4 in year 1, 6 in year 2) is preceded by a group tutorial session with the member of staff in charge in which progress is presented and discussed and objectives for the next laboratory session are agreed, including the relevant preliminary research. (Obviously the first and last sessions are slightly different.) Staff can provide whatever information they think is relevant, but they are asked not to turn the tutorial into a lecture. Staff supervise the laboratory work to a variable degree, but in all cases are present for only a part of a session.

While there is clearly a close relationship with standard group projects there are also some differences. The presentation of the projects to students is couched in the language of a problem rather than an endpoint. So for example, the deliverable in the stereo-imager project is not the hardware, but the solution to the problem of determining distances. There is a focus on process as well as endpoint. By this I mean that the group is expected to operate within a defined structure, not just left to get on with it. We use our local PBL model for this[4], although any PBL structure would be equally applicable. The performance of the group process is assessed (rather lightly), not just the deliverables.

One preliminary observation, which comes across strongly, is that students pick up very quickly on the degree of staff engagement; it may be this aspect ...that dominates the responses to PBL

Some outcomes
We do not yet have the results of a formal evaluation process from interviews that have been carried out independently with staff and students or from student questionnaires. However, what we do have is intriguingly mixed. Anecdotally, and from casual observation, there was a much greater engagement of staff with their projects than has been common in the laboratory with standard experiments. The student viewpoint is difficult to disentangle, partly because they have not experienced the experiments and lecture courses that have been replaced.

There appears generally to be a greater involvement (despite one comment 'why can't we just do ordinary labs?'), but as yet no evidence of greater retention of subject knowledge.

Further research will hopefully tell us what more we can learn about embedding PBL in the physics core. One preliminary observation, which comes across strongly, is that students pick up very quickly on the degree of staff engagement; it may be this aspect (and the now well-known positive effect of collaborative learning[5]) that dominates the responses to PBL.

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Contribute to the next issue!

If you would like to contribute to the next issue in the first instance please send a short summary/ abstract, by 31st March 2007, to the editor...

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The deadline for full articles is 30th June 2007.

This is your chance to contribute to a a journal highlighting education in the physical sciences at the tertiary level.

There is a lot of innovation within the community but not always the opportunity to share it with like minded colleagues.

New Directions is a way of addressing this issue. By publishing successful examples of effective practice we hope to help colleagues avoid re-inventing the wheel and enable people to share ideas and experience. Another benefit of this publication is that many examples are not restricted to any one discipline but can provide inspiration across the whole of the physical sciences.

What is routine for one colleague may appear innovative to another so this publication aims to promote this work, even if it may not appear to be cutting edge to the person concerned. Therefore, whilst *New Directions* will aim to promote innovative ideas, we also welcome tried and tested approaches that have proved successful in supporting teaching and learning practice.

We are seeking the following as contributions…

Reviews of topics in physical sciences education and educational research

These are normally invited contributions from ‘expert’ practitioners. Typically they would be informed, accessible articles of up to 3000-4000 words and would cover the teaching, learning and assessment literature for the previous 12 months. Examples would be: Pedagogic research in the physical sciences; E-learning; Assessment; Outreach (for recruitment).

Communications

These would be contributions in response to a ‘call for papers’ from the physical sciences education community (and might include: innovations, effective practice, what worked for me, what failed for me etc). These articles should present the context, the problem, how it was tackled and the evaluation and possible further work. They should not be just descriptive or narrative. Communications would typically be up to 1500-2000 words although longer contributions would also be considered.

Initiatives

These would be invited reports from projects (eg FDTLs and CETLs). Typically, these reports would be up to 1500-2000 words.

All submissions also should include contact details and a short summary/abstract.

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