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New Directions

in the Teaching of Physical Sciences

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Editorial

New Directions has now become an annual publication from the Higher Education Academy Physical Sciences Centre in association with πCETL, The Physics Innovations Centre for Excellence in Teaching and Learning. Our thanks to all those who have contributed to this issue which we think is a significant publication for those interested in improving teaching and learning in higher education.

In this this issue, of 80 pages, we have three reviews covering; aspects of e-portfolios, context or problem-based learning and peer assessment. Additionally, we have 14 communications from practitioners in the teaching and learning field; including articles from the two overseas speakers we invited to the UK this year, Melanie Cooper from Clemson University in the USA and David Mills from Monash University in Australia.

After the review of Outreach in issue 2, last year, that theme figures largely too in this issue; but amongst others there are also articles considering how to improve the ‘student experience’, safety, MCQs and communication science. There is a good mix of contributions from the physics and chemistry community but most of the articles have enough ‘generic’ material to be of interest to all in the physical sciences.

We hope you will find much of interest.

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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Supporting Student e-Portfolios

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Abstract
Historically, the term portfolio has been used to describe a folder of work used predominantly for skill recording and display purposes. It was mainly paper based, usually begun when its author was a student and developed over a working lifetime. More recently the term has been taken up for use in schools and colleges, describing a more modest folder holding work from a particular project or an entire course, and in professional fields as a collection of material required to evidence competence for accreditation or to prepare for assessment.

Since its inception as an evolution of this traditional portfolio, the electronic portfolio or e-portfolio has attracted a great deal of interest from around the world where there is ready access to suitable technology. This interest continues to grow with increasing numbers of students and professionals being encouraged, or required, to produce e-portfolios. This article focuses on e-portfolios in the higher education (HE) sector, principally those authored by students. Its purpose is to provide a basic introduction to e-portfolios: what they are, how they are being used, potential benefits and challenges, and guidance for their successful introduction.

Introduction
Historically, the term portfolio has been used to describe a collection of work, mainly paper based, usually begun when a student and developed over a professional's lifetime, predominantly by those in the arts fields. More recently, it has been taken up for use in schools and colleges, describing a more modest folder holding work from a particular project or an entire course. In professional fields, the term is often used to describe a collection of material required to evidence competence for accreditation or to prepare for assessment.

a student e-portfolio is an archive of material, relating to an individual, held in a digital format.

In the early 1990s the *electronic portfolio*, or *e-portfolio*, began to emerge as an evolution of the traditional portfolio but taking advantage of the increasing availability of digital media. Interest continues to grow with increasing numbers of students and professionals being encouraged (or required, within the health sciences and legal fields) to produce portfolios. This is supported by a wide array of software packages designed specifically for their creation and dissemination.

What is an e-Portfolio?
This should be but is by no means a straightforward question[1]. A possible definition, the one that will be used here, is that a student e-portfolio is:

> *an archive of material, relating to an individual, held in a digital format.*

Examples of actual student e-portfolios
- University of Warwick
  http://www2.warwick.ac.uk/cll/skills/eportfolio/crs/examples/
- LaGuardia Community College
  http://eportfolio.lagcc.cuny.edu/basic_gallery.html
- eFolio Minnesota
  http://www.efoliominnesota.com/
- New York City College of Technology
  http://eportfolio.citytech.cuny.edu/
- St Olaf College
  http://www.stolaf.edu/depts/cis/web_portfolios.htm

Though professionals and institutions may generate their own e-portfolios, this article focuses on students as the principal authors.

e-Portfolio Contents
The main contents of an e-portfolio are typically:
- evidence of achievement
- author statements about the evidence
- feedback on the evidence
- other personal material pertaining to the author

In North America, where e-portfolios first came to prominence, the contents tend to focus on evidence of achievement. In UK HE, e-portfolios tend to be used in the context of *personal development planning* (PDP) so a balance of material is encouraged. The actual contents of an e-portfolio will depend on the student, purpose of the e-portfolio and the intended audience.

e-Portfolio Uses
An e-portfolio is very flexible and has many possible uses, including:
- storing materials
- sharing materials with an outside audience
- aiding self analysis
- supporting academic and profession goals
- supporting external assessment

A single e-portfolio may be used for more than one purpose or it may be more straightforward for a student to construct a number of different e-portfolios, a view postulated in *Becta's View: E-assessment and e-portfolios* [http://ferl.qia.org.uk/display.cfm?resID=13337].

Types of Student e-Portfolios
Generally, student e-portfolios fall into two main categories:

<u>Developmental student e-portfolios</u>
These include:
- *transitional* - those aimed at facilitating transfer of data
- *learning* - those aimed at supporting self-development activities and processes, such as PDP or work placements

<u>Presentational student e-portfolios</u>
Also frequently referred to as *showcase*, this type is used in support of the author, for instance in the case of:
- applying for a course of study/job/work placement
- building CVs
- external assessment
- accreditation
- appraisal

e-Portfolio Assessment
Opinion is divided on both whether e-portfolios should be used for assessment purposes and if so, how this should be undertaken.

<u>Methodologies</u>
e-Portfolios can be used for formative and summative assessment[1,2]. The assessment itself may be done in a manner which looks for evidence of learning gains[3] or by comparing it with scoring rubrics or standards[3,4].

<u>Opportunities and Benefits</u>
Supporters of e-portfolio assessment point out that it fits with the movement away from standardised testing and towards alternative or *authentic assessment*[4-7] providing a truer picture of the student's ability[8].

As well as this, e-portfolio assessment may offer other benefits, such as:
- increasing student reflection[9]
- revealing information not shown by other assessment methods[2]
- making students more active in assessment and their learning as a whole[3,10,11]
- giving students more ways to demonstrate their knowledge[5]
- making longitudinal studies possible[8]

Additionally the process may cause educators to reflect on course content and teaching methods[3].

<u>Challenges</u>
Even those who support e-portfolio assessment acknowledge the many challenges it can bring including:
- authenticating work[12]
- deciding what constitutes 'good' work[13]
- uniformity of assessment between assessors[9,14]
- the time necessary to read and assess work[4,6,9]
- how to score evidence[9,12]
- whether the credit awarded appears to be proportionate to the time invested[15]
- whether the assessment is unduly influenced by the student's technical skills or lack thereof[12]

Teachers may feel that there is a conflict between their role as an assessor and as a mentor[16] and knowing how much guidance they can give to a student without challenging the 'ownership' of the e-portfolio[13]. Although it has been emphasised how important it is to include reflection[14] students have been known to object to having their reflections assessed[15].

Software Options
A range of options is available which subdivide into three basic types:
- in-house solutions (e.g. RAPID Progress File, LUSID)
- commercial software
    - dedicated e-portfolio software (e.g. *PebblePad*, *Folio*)
    - generic software tools (e.g. *SharePoint*)
- open source software (e.g. OSP *ePortfolio*, PETAL)

> In the course of her research, Helen Barrett has developed many versions of her own e-portfolio using a variety of open source and generic tools, including blogs, which can be viewed on her website at http://helenbarrett.com/myportfolio/versions.html#1

<u>Making a choice</u>
For those trying to decide which e-portfolio system to adopt, the CRA (The Centre for Recording Achievement) have developed a set of in-depth questions that should enable an institution to make an informed choice[42]. For those not in a position to make the choice it is important to understand what a system can offer so that it can be used to its best advantage.

Benefits
<u>Potential Benefits of the e-Portfolio</u>
Since the e-portfolio is very much an evolution of the traditional portfolio, many of the benefits arising from the construction and use of the traditional form can also justifiably be attributed to the electronic version[17] , such as:

- developing learning
- supporting self-assessment
- encouraging reflection
- fostering self-motivation

Academics themselves can benefit from the process of constructing an e-portfolio in terms of their continuing professional development (CPD) and by doing so, they are also uniquely prepared to help students do the same[18]. Indeed, it could be argued that students are unlikely to be convinced of the value of constructing an e-portfolio by those who have not engaged in the process for themselves.

Furthermore, the e-portfolio offers several benefits over the traditional portfolio[12,17,19-21].

Potential Benefits over the Traditional Portfolio

For the Student

Storage Space

An e-portfolio allows a relatively large amount of material to be stored and shared in a cost effective way, on either a CD or DVD, or online[6,22].

Data Types

Since they are electronic, e-portfolios can contain not just text data but material such as audio files, video files and slide presentations. Much of this is in an electronic format to start with which makes it more convenient to keep it this way[23].

Adaptability and Flexibility

It is relatively easy for material to be added, deleted, adapted or rearranged compared with that in a traditional portfolio, so it is much more likely to be kept up to date than its paper counterpart.

Audience access

If the e-portfolio is hosted on a web site, prospective viewers can be granted access by being given the site address and any necessary access permissions. The e-portfolio tool may also allow different arrangements of the material to be seen depending on the 'access' given to the audience.

Key Skills Development

Developing an e-portfolio gives individuals the opportunity to learn, develop and display key skills[12,18,22].

For the Employer

e-Portfolios have been said to offer a more 'authentic' analysis of an individual[8,23,24] because they offer a fuller picture of their achievements than, say, exam results.

For an Institution

Adoption of an e-portfolio programme for students offers several potential opportunities for the host institution[3,25,26] including:

- helping with student transition
- giving an insight into student progression through a specific course or in general
- offering the opportunity for dynamic course feedback from students
- helping to support work placements
- by showcasing student achievement it can also demonstrate the success of the institution
- encouraging institutional reflection and improvement

Challenges

Any new system, particularly one with a technological basis, offers its own challenges. These include:

Technical Challenges

e-Portfolio Tool Set

Whatever system is chosen it has to meet the needs of the users, be sufficiently straightforward for beginners, and yet be sufficiently flexible for the more advanced[15,24,27].

IT Support

The amount of support needed for both institution staff and students should not be underestimated particularly when the system is first introduced[28]. Staff and students will need training and to know that they can obtain assistance when needed[29].

Interoperability and Standards

With the increase in popularity of e-portfolios, key areas of interest are those of interoperability, which is the transfer of data from one system to another whilst maintaining its integrity, and standards. These issues are of particular importance when the e-portfolio is to be used to assist transition or to support lifelong learning (where ideally individuals would be able to start their e-portfolio at any stage in their lives and always be able to take it with them).

Access

Although the e-portfolio offers clear advantages over the traditional portfolio when it comes to allowing access this brings corresponding challenges, for instance:

- deciding who has permission to access the e-portfolio and who sets those permissions
- providing all students with appropriate access to their e-portfolio[30]
- deciding how long the institution will host and allow access to the e-portfolio after a student has left and if there will be a charge for this facility
- maintaining the security of the information in the e-portfolio

Resource Challenges

People

The most important resource will be the people involved:

- academic staff to introduce and support the project, including providing prompt feedback to students and guidance in reflection, which may be unfamiliar or problematic for some[31]
- technical staff to support the system
- support emanating from the top levels of the organisation

Time

Time is often cited as an important consideration when implementing an e-portfolio system[6,19,32]. Planning needs to be done to analyse the time demands of:

- training staff and students
- introducing the e-portfolio project
- providing technical and academic support
- giving feedback to students

and also how this may impact upon the curriculum.

All authors will need to be aware of the significant amount of time it may take to construct an e-portfolio and keep it up to date, especially in the early stages, but that this will become less of an issue as their confidence and proficiency increase.

Costs
For the institution, it is worth noting that costs include:
- the software and hardware, its installation, maintenance and repair
- possible additional storage as the size of e-portfolios and their number increase
- training for existing staff or employing and training new staff

Legal and Ethical Challenges
The main areas to consider are those of:
- data protection
- intellectual property rights, and
- accessibility

Data Protection
The **Data Protection Act 1998** (DPA 1998) seeks to establish the responsibilities of those who determine the gathering and processing of personal information and the rights of those who are the subject of that information. For certain types of e-portfolio system, the institution does not exercise any control over the data gathering or its use and is therefore not subject to the Act. In all other cases, the institution must inform the Information Commissioner's Office (ICO) of this and indicate the purpose(s) for which it intends to process personal information and the intended operational uses of the e-portfolio system[33,34].

Intellectual Property Rights
Intellectual Property (IP) Law seeks to protect works of human creativity and the rights of the creators and owners, whilst allowing public access. The main area of IP law in this context is copyright.

Copyright is governed by the **Copyright, Designs and Patents Act 1988** (CDPA 1988). Copyright ownership is generally held by the person who created the work, who then has rights over the work and how it is used. Institutions need to be fully aware of who owns the copyright on student work, as do students themselves. Awareness is paramount in avoiding problems in such instances where students include the work of colleagues or information from work placements in their own e-portfolios[33].

Disability Legislation
The **Special Educational Needs and Disability Act 2001** (SENDA 2001) requires institutions to take reasonable measures to ensure disabled students are not placed at a disadvantage and make reasonable adjustments where possible[33]. Institutions should also be aware of their responsibilities to their disabled employees under the terms of the Disability Discrimination Act 1995 (DDA 1995).

Other Legal and Ethical Issues
Institutions will be well advised to consider the implications of student e-portfolios containing material that might bring charges of, for instance, plagiarism or defamation when published, or leave authors open to the possibility of 'identity theft'[35].

Briefing papers on the topic of student plagiarism, its avoidance and detection, have been produced both by the HEA Physical Sciences Centre [www.heacademy.ac.uk/assets/ps/documents/briefing_papers/ps0005_plagarism_feb_2005.pdf] and by JISC (Joint Information Systems Committee) [www.jisc.ac.uk/uploaded_documents/JISC-BP-Plagiarism-v1-final.pdf]. JISC also fund the JISC Plagiarism Advisory Service (JISC PAS) for academics and students.
In the case of student e-portfolios, clear guidelines on content should be worked out as soon as possible along with suitable policy on the action to be taken if rules are breached.

Further Information on Legal and Ethical Issues
- Acts of Parliament can be viewed in full online and print copies obtained from the Office of Public Sector Information (www.opsi.gov.uk)
- A clear overview of the DPA 1998 can be found in the Data Protection FactSheet: What is the Data Protection Act (DPA)? produced by the ICO (www.ico.gov.uk)
- JISC Legal Information Service has commissioned a number of useful legal studies relating directly to e-portfolios, which can be obtained from their website (www.jisclegal.ac.uk).
- JISC Plagiarism Advisory Service (JISC PAS) (www.jiscpas.ac.uk)

Personal Challenges
A highly significant feature of any system is of course the people within it. All will come with their own attitude towards new technology and this can work both for and against e-portfolios. Some have found that the 'e' nature of the tool actually inspires and encourages people to engage with it[36]; however, negative past experience with technology or a feeling of insufficient previous experience can work against it. Level of initial technological expertise and access to technology cannot be assumed. This is equally true for both those who are building their e-portfolio and those involved in supporting them within the institution.

For some, attitudes towards e-portfolios or the PDP/CPD framework in which they are placed within the institution or profession can determine whether or not an individual wishes to engage with the process.

Positive support and encouragement from an institution, professional body or peers can do much to aid success[37,38]. It is generally agreed that the way the project is initially introduced has a significant impact on how the project is accepted[39]. This is why thorough preparation before the e-portfolio is launched is so important.

Successful Introduction of e-Portfolios

Once a system is chosen, sources[28,40,41] indicate many common recommendations which assist the successful implementation of an e-portfolio system:

- implementation and integration needs to be broken down into smaller projects which can be built upon
- from the outset it should be understood that this is a long term undertaking
- implementation will need support from above and 'champions' should be involved from the beginning
- the purpose of the e-portfolio needs to be clearly identified and integrated into the curriculum
- the programme may need to be mandatory at least in part or at the beginning to overcome initial resistance

Staff need:

- to be shown the possible positive outcomes to the venture and examples of best practice
- to see this as being in the interests of the student
- support and training to acquire the appropriate skills to support students including technical skills and giving feedback
- to go through the process of creating an e-portfolio themselves

Students need:

- clear reasons to get involved
- support and training to acquire appropriate skills and not be able to opt-out due to lack of skills
- to be given advice on choosing artefacts
- to be taught how to reflect
- encouragement and regular feedback
- to see good examples
- to know if and how the e-portfolio will be assessed

Further information about the implementation of e-portfolios, e-portfolio projects and case studies

- CRA [http://www.recordingachievement.org]
- JISC [http://www.jisc.ac.uk]
- EIfEL [http://www.eife-l.org]
- SURF [http://www.surf.nl]

Examples of e-Portfolio Use in UK HEIs

University of Gloucestershire
PebblePad is being used by most first year students studying in the Department for Natural and Social Sciences.

Kingston University
All level 1 students in the School of Pharmacy and Chemistry are offered support to use the ePortfolio tool on Blackboard.

Loughborough University
Loughborough's electronic PDP tool RAPID is used with Science and Engineering Foundations Studies (SEFS) students in the Learning and Communication Skills module.

Northumbria University
The ePortfolio tool on Blackboard is being used by first year students including Foundation degree students within the School of Computing, Engineering and Information Sciences.

University of Paisley
First year students in science & engineering use Blackboard to produce an e-portfolio.

University of St Andrews
The e-portfolio tool within WebCT/Blackboard is being piloted currently with level 3 students in physics and astronomy, moving to many first year students in the coming session.

University of Ulster
The University of Ulster has a Personal Development System (PDS), which includes an e-portfolio.

University of Wolverhampton
The *PebblePad* ePortfolio system is used by students, principally first year and second year undergraduates across the following subject groups: Biomedical Science, Environmental Science, Biological Sciences, Pharmacy, Physiology and Clinical Physiology. Some use is made by postgraduate students.

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Context and Problem-based Learning

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Abstract
Context based learning is any learning that places content within a meaningful context. CBL has been demonstrated to enthuse and engage learners and is increasingly being used in sciences, especially at pre-University level. Problem-based learning can be viewed as a sub-set of CBL. In PBL, the context is framed as an open ended problem scenario. The problem is encountered before knowledge is in place and acts as the driver for independent learning. PBL has been demonstrated to enhance understanding, increase motivation and develop a range of transferable skills. The use of CBL and PBL in the physical sciences will be reviewed.

Context and problem-based learning are approaches that are becoming increasingly popular in Higher Education. The aim of this article is to introduce the two approaches and provide some exemplars from within the physical sciences.

What is context-based learning?
Context-based learning (CBL) in its broadest sense describes the cultural and social environment within which students, tutors and institutions operate. This context is influenced by communications media to provide the academic community with a common culture. Hansman[1] states that adult learning only takes place when this context and learning tools or methodologies come together to promote interaction between learners.

PBL is different from other forms of learning in that the students work in teams throughout and move towards a solution to the problem together by gathering and sharing information and ideas

Another aspect of context-based learning is the use of applications to illustrate and illuminate the curriculum. For science students this usually means providing them with opportunities to test theories with real world examples. The use of a meaningful and appropriate context has been shown to motivate and enthuse learners[2,3]. However, introducing these real examples after all the theory has been covered may not be the best approach.

It has been suggested[4] that science concepts exist in three forms which can be thought of as corners of a triangle (Fig 1) and that each form complements the other. These forms are

- the *macro*: what can be seen, touched and smelt;
- the *submacro*: atoms, molecules, structures, forces, etc
- the *representational*: symbols, formulas, equations, etc

Johnstone argues that we encounter life on the macro level. On the macro level science is what students do in the laboratory or experience in real life. However, science, to be more fully understood, has to move to the submicro situation where the behaviour of substances and physical phenomena are interpreted in terms of the unseen and recorded in some representational notation and models. Science is traditionally taught almost entirely from the submicro and representational forms with the macro, or real life, aspects often being divorced from the rest of the subject or added as an afterthought. Where this approach has been reversed to use a real life context to drive the learning evidence has demonstrated that students engage much more enthusiastically with their learning[5-7]. It is this definition of context-based learning that is used in this paper.

Why use context?
An extensive review of 66 studies on interventions with 11-16 year old pupils found that the use of context motivates and fosters positive attitudes to science without compromising learners understanding of scientific ideas[8]. The use of context based learning is increasing in pre-19 education. The Salters A-Level course (*Salters Advanced Chemistry* from http://www.york.ac.uk/org/seg/salters/chemistry/index.html) aims to "emphasise the ways chemistry is applied and the work that chemists do" and includes modules on topics such as 'The Oceans' to teach enthalpy, entropy and solubility and a

module called ‘The Steel Story’ to teach redox, electrochemistry and *d*-block chemistry. The Salters Horners A-Level physics course (*Salters Horners Advanced Physics* from http://www.york.ac.uk/org/seg/salters/physics/index.html) uses modules such as ‘Transport on Track’ to teach force, momentum, electromagnetic forces and ‘Build or Bust’ to teach simple harmonic motion, forces vibrations, resonance and damping. The Higher Education sector has also seen a growth in provision that presents science in real-world contexts, such as forensic science, sports science and astronomy.

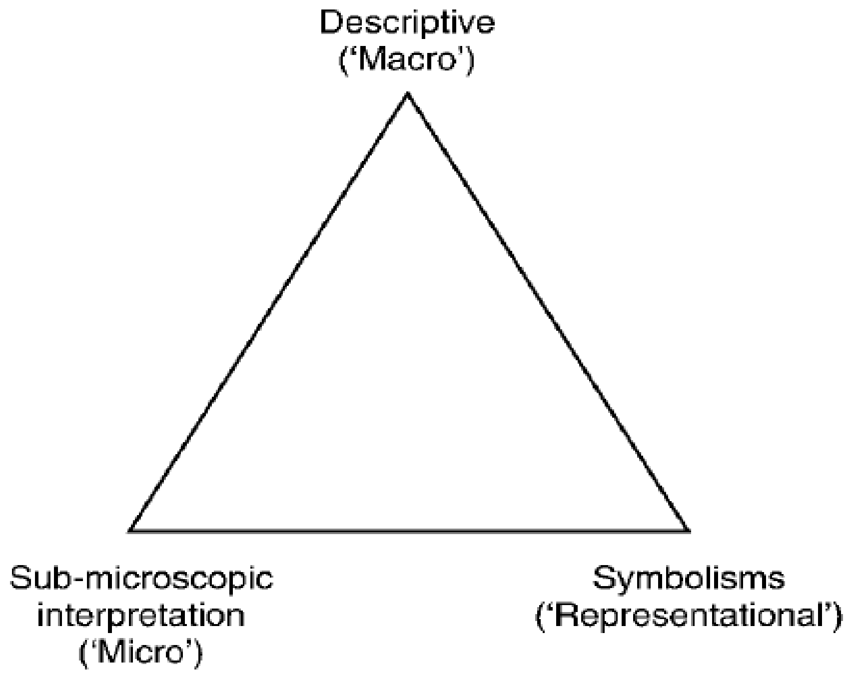

Figure 1: Three levels of science concept representation

What is problem-based learning?
Problem-based learning (PBL) can be considered to be a sub-category of context-based learning. In PBL, as in CBL, the curriculum is organised and driven by real life contexts. In PBL these contexts are presented in the form of problem scenarios. An important feature of PBL is that the problems or scenarios are encountered before all the relevant learning has taken place and act as the driver for new learning. Thus PBL is distinct from problem solving where problems are generally encountered after learning had taken place. A course that is delivered entirely by PBL would have no lectures and students would work in groups throughout the process, with tutors acting as facilitators. A good introduction to PBL has been published by Boud and Feletti[9] which contains short chapters grouped into themes, including getting started, design and implementation, and assessment and evaluation.

Problem-based learning first appeared 1969 as a new approach to medical education at McMaster University in Canada. It was developed as an educational approach drawing on philosophy, psychology, and educational research. According to Barrows[10], PBL can be explained as “the learning that results from the process of working toward the understanding or resolution of a problem”. Savery and Duffy[11] have used Barrow’s model to demonstrate that PBL fits easily within the framework for effective learning described by the constructivist learning theory. Constructivism is a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in. PBL learning is a process of building on prior knowledge, problem solving, using critical thinking approaches and reflecting[12].

There has been considerable research carried out that compares PBL medical students with traditional medical students. Many of these findings may be generalisable to the application of PBL in other disciplines. For example, research into reasoning skills found that PBL students tended to reason backwards from clinical information to theory whereas traditional students tended to reason forward from theory and stayed closer to clinical facts[13]. There is evidence that PBL students perform less well on written examinations of knowledge[14] but perform better on skills based assessments[15]. Some studies have shown that PBL students show different study skills to conventional students. PBL students have been found to use a wider range of information sources and feel more confident in using information[16]. PBL students have been found to be more likely to study for meaning than conventional students[17].

How does PBL work?
PBL is different from other forms of learning in that the students work in teams throughout and move towards a solution to the problem together by gathering and sharing information and ideas. There are several formal models of PBL and these are strictly adhered to in some disciplines, particularly medicine and associated professional disciplines,

such as nursing. As PBL is relatively new in the sciences, practitioners are developing flexible models of PBL and implementing them in ways that suit their own particular context. Some examples are discussed later. However, the main features of PBL are real world context, group work, problem solving, acquisition of new knowledge and presentation of outcomes or product.

Generally, during the first classroom session the students are divided into groups and presented with the problem. They may brainstorm in order to clarify the nature of the problem and identify their learning needs. They may delegate roles within the groups and share existing knowledge. The tutor's role is one of observation, guidance and support. Outside the classroom session, the students engage in independent study in order to fill any gaps in subject knowledge. They come together again in a group or classroom session to share and critically evaluate resources and information gathered. Using the newly acquired information they work towards a solution to the problem. Again, the tutor's role is one of guidance and support. This cycle of independent study, group interaction and critical analysis may be repeated as many times as dictated by the problem. Eventually the students present their solution and reflect on the process and solution.

A search under 'problem-based learning' using the Google search engine finds eight million hits with no trouble at all.

What about assessment?
As this is a very different type of learning activity it may not be appropriate to assess students in a traditional way. The assessment should be matched to the desired learning outcomes. Assessment may focus on the solution to the problem, or the problem solving process or the skills development aspect. Tutors must decide whether they wish to give each member of a group the same mark or whether they wish to build in an individual element. Students may be involved in assessing each other's contribution to the activity or may be involved in self-assessment and reflection. Useful assessment tools include; reflective logs and diaries, written reports, oral presentations, posters or the product from practical activity.

Examples from chemistry
Context and problem-based learning in chemistry has grown in popularity over the past 5 years and new and innovative examples are continuing to appear. Belt et al have produced a suite of C/PBL resources for analytical chemistry drawing on contexts in industrial, pharmaceutical, environmental and forensic chemistry[6,18]. These resources deliver learning outcomes in analytical chemistry as well as a range of transferable skills. Green chemistry has also been used as a context for chemistry[19,20] where the aim has been to raise the issue of green chemistry as it relates to the chemical industry. In another example, sport was used as the context to meet learning outcomes in biochemistry, simple thermodynamics and materials chemistry[21]. Environmental chemistry is another context that lends itself to delivery of the chemistry curriculum[22]. It might be expected that the traditional branches of chemistry; inorganic, organic and physical, would be more difficult to deliver via context or problem-based learning as the applications and real life contexts are less obvious. Some success has been achieved however and a collection of resources in these braches has been published by the Royal Society of Chemistry[23]. The PBL approach has also be applied successfully to the undergraduate chemistry laboratory. McGarvey has collaborated with industry to produce a suite of physical chemistry experiments[24] and McConnell et al have produced PBL mini-projects which utilise contexts such as cosmetics, food and forensic science[25].

Examples from physics
Problem-based learning in physics has emerged in the UK and Ireland over the last 5 years, largely stimulated by the efforts of groups at Leicester University and Dublin Institute of Technology. A comprehensive guide to PBL in physics which contains a large number of examples, including the work of these two groups, has been published by the Physical Sciences Centre[26].

PBL has been used in the undergraduate physics laboratory[27] and in small group projects[28]. One interesting application of PBL has involved the use of images, rather than the usual textual questions, equations and formulas[29]. An extensive post-16 curriculum uses contexts in sport, food, and the environment to teach basic physics[30]. The authors of this curriculum warn against using contexts which potentially alienate sections of the student population and to take care to consider gender and cultural issues

PBL resources on the web
A search under 'problem-based learning' using the Google search engine finds eight million hits with no trouble at all. Most PBL websites give a definition of the key characteristics of problem-based learning and extol the virtues of the approach. Most give extensive lists of links to other sites and, consequently, almost any PBL website is a reasonable starting point. Few attempt to give any sort of realistic advice on implementation, overcoming difficulties, preparing staff and students or writing problems. Even fewer sites give examples of problems and many that do give materials which are, to say the least, disappointing. Much of what is presented as PBL is really no more than reasonably creative problem solving.

Most quality PBL sites originate in the USA, Canada and Australia. Much of what is available is in Medical education but is often still applicable to other disciplines. Many of the sites are interdisciplinary and provide resources and ideas which many practitioners may find useful. What follows here are brief summaries of the some of the more interesting and useful aspects of several sites on PBL.

Project LeAP (Problem-based LEarning in Astronomy and Physics) was a three-year FDTL project. The project aimed to increase the profile of problem-based learning in university Physics and Astronomy courses. The University of Leicester lead the project consortium, with the Universities of Hertfordshire, Reading, and Sheffield as partners. The project website includes a comparative analysis of PBL within physics, case studies, exemplar support materials for students and tutors, and original PBL problems. Although the project is now completed the webpage remains updated and the PBL work is now sustained under the activities of the π-CETL, Centre for Excellence in Teaching and Learning. An annual PBL summer school is organised each July.
(http://www.le.ac.uk/leap)
(http://www.open.ac.uk/picetl/)

Much of what is presented as PBL is really no more than reasonably creative problem solving.

The University of Adelaide's Advisory Centre for University Education is home to 'Leap into PBL'. This site is aimed primarily at the university teacher who wishes to explore this approach for the first time, but may also be useful to the teacher who has 'dabbled' with PBL. The site aims to provide a structure around which practitioners can build their own course. It includes a step-by-step induction to PBL and covers a wide range of issues such as training staff, preparing students, assessment, evaluation, dealing with non-participation, keeping the groups going, timetabling sessions, etc. It also provides guidance on writing problems that do not gloss over the effort and time involved. This s a very useful and practical site and is a good staring point, especially for the lecturer new to PBL.
(http://www.adelaide.edu.au/clpd/materia/leap/leapinto/ProblemBasedLearning.pdf)

The National Center for Case Study Teaching in Science is a real treasure trove of context-based case studies. There are many examples of cases covering many areas of science and links to a large number of sites which could provide ideas for new cases. This is an excellent place to start if you are thinking of writing your own problems.
(http://ublib.buffalo.edu/libraries/projects/cases/ubcase.htm)

The Problem-based Learning Initiative at Southern Illinois University concentrates mainly on medical education but is very useful for the basics such as the essential requirements for PBL. If you are interested in medical education then they have a range of books, videos, PBL modules and patient simulations to buy. The bibliography is very comprehensive.
(http://www.pbli.org/core.htm)

The San Diego State University Distributed Course Delivery for PBL site provides an on-line workshop in PBL which could form the basis of do-it-yourself staff development. This could be another good starting point for academics new to PBL. The 'Learning Tree' section provides comprehensive coverage of the subject and is particularly strong on assessment, implementation and overcoming barriers and obstacles. The site also includes an extensive bibliography.
(http://edweb.sdsu.edu/clrit/home.html)

The University of Delaware site hosts a number of sample problems taken mainly from the sciences. By far the most useful feature of this site is the PBL Clearinghouse which is a searchable collection of many peer reviewed problems. The Clearinghouse is accessed via an email user name and password but these are available easily and you can be signed up within minutes. Once into the Clearinghouse, users can search by keyword, author or discipline. There is also an invitation to become an author or reviewer. This is a really excellent resource.
(http://www.udel.edu/pbl/courses.html)

Of course McMaster University in Canada has a long tradition in PBL. One staff member, PK Rangachari, has some very useful advice related to writing problems in his 'Writing Problems: A Personal Casebook'. This casebook discusses the many aspects of writing good quality problems and includes many examples drawn mainly from the biomedical, and biological sciences.
(http://www.fhs.mcmaster.ca/pbls)

The Maricopa Center for Learning and Instruction hosts a searchable database of links which is more useful than most as the search can be refined, so producing a sensible number of more relevant links.
(http://www.mcli.dist.maricopa.edu/pbl/problem.html)

Other useful sources of information

PossiBiLities; PBL in Physics and Astronomy, Raine D and Symons S, Higher Education Academy Physical Sciences Practice Guide, 2005 (www.heacademy.ac.uk/physsci).
Anyone interested in finding out more about the practicalities of problem-based learning should start with this publication, whether they are a physicist or not. It is full of sensible advice and good ideas and will be invaluable on the journey from devising problems, to training staff, to implementation and assessing student outcomes.

The Power of Problem-Based Learning: A Practical "How To" for Teaching Undergraduate Courses in Any Discipline, Duch B. J., Groh S. E., Allen D. E., (ed), Stylus , 2001.
Useful advice from various authors, many of whom are from a science background.

Foundations of Problem-based Learning, Savin-Baden M., Major C. H., Open University Press, 2004.
Explores the foundations of problem-based learning and its use. It includes discussion of academic development, cultural diversity, assessment, evaluation and curricular models.

Problem-based Learning in Higher Education: Untold Stories Savin-Baden, M. Open University Press, 2000.
Explores both the theory and the practice of problem-based learning and considers the implications of implementing problem-based learning.

Problem-based Learning Online, Savin-Baden M. and Wilkie K., Open University Press, 2006.
A collection of papers which explore the development of an online pedagogy for problem-based learning.

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Peer Assessment

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Abstract
Peer assessment is the process whereby students provide formative or summative feedback to fellow students about their work. There have been many decades of research into the potential benefits of peer assessment and numerous studies have shown that peer assessment offers real educational, and sometimes social benefits for students. In addition, self assessment is often included alongside, but the benefits are sometimes disputed. This article will provide a brief summary of the research establishing the educational benefits of peer assessment and self assessment.

There has also been a lot of work in recent years exploring the use of technology to support peer assessment. This work will be reviewed and recent examples of peer assessment in the physical sciences will be highlighted.

What is peer assessment?
Feedback from different sources, such as mentors, tutors or lecturers can greatly enhance the student learning process. Fellow students, peers, are another source of feedback and peer assessment, the formative or summative feedback provided by peers, can offer a number of educational benefits. Peer assessment involves students giving feedback to each other to grade their work or performance using relevant criteria[1]. Boud, Cohen and Sampson[2] discuss the merits of peer assessment and suggest that it can be part of an important strategy in the repertoire of approaches to teaching and learning.

Peer assessment can be used in a more supportive way, rather than simply enabling students to grade each other. Roberts[3] refers to peer assessment as a process which allows learners to reflect critically upon the learning of their peers. Peer assessment is also a reciprocal process in that the student providing feedback also benefits from increasing their own understanding. This is achieved by students having to critique and review someone else's work and thereby reflect on their own understanding or performance.

Peer assessment can be used in a more supportive way, rather than simply enabling students to grade each other.

A learning activity involving peer assessment may take a number of forms. At its simplest, peer assessment may involve peers providing formative feedback to one another. With large numbers of students, where peers are working in groups, this feedback may be formative (e.g. informal feedback) or summative, whereby each group member provides marks or grades for their fellow peers, and may be one-to-one or many-to-many.

Benefits of peer assessment
Although peer assessment can be used as a particular approach to teaching in its own right, it is often coupled with peer learning, where student peers work together to support each other's learning and then peer assess each other's progress. Johnson, Johnson and Smith[4] discuss the rationale for engaging in peer work and define the different types of engagement. They identify the 'old' paradigm in which education is competitive between students who are attempting to out perform each other. They also discuss 'cooperative' learning where students cooperate to achieve a goal – though some argue that cooperation is individualistic and students do not really learn together. Collaborative learning is more commonly used in this context, but Bruffee[5] discusses the merits of both approaches in greater detail. Cooperative learning may be considered strategically different from collaborative learning, but most people today tend to mean the social interaction of peers to promote deeper learning (for example, Gillies and Ashman[6]).

Chin[7] lists some of the main benefits of peer collaboration, including the promotion of learning through social interaction, the development of self confidence and the provision of a network of support. Kagan[8] also discusses the wide range of benefits of peer collaboration, such as supporting mixed ability students, meeting the needs of the curriculum and the positive outcomes, both personally for students and collectively. Bruffee[5] quotes Theodore Newcomb saying that the single most powerful force in undergraduate education is peer-group influence.

In addition to the benefits for students linked directly to the learning and understanding of their subject, there are a number of other benefits of peer assessment. Chin et al[9] highlight some of these including developing self reflection, developing transferable skills, such as better time management, and critical thinking skills, and the potential for saving time on task. Orsmond[10] discusses some of the benefits of peer assessment in further detail.

Issues with engaging with peer assessment

Perhaps one of the first issues with respect to peer assessment is ‘does it work?’ There have been a number of studies exploring the validity and reliability of peer assessment, such as by Falchikov and Goldfinch[11] who have shown that well designed peer assessment is a reliable and valid method of assessment. Topping[12] also reviews a wide range of literature and concludes similarly that peer assessment is a valid and reliable approach to teaching.

Another issue is whether peer assessment can be successfully implemented in the curriculum, given current constraints of time and classroom space. There are a wide range of methods available, some of which are highlighted by Barkley, Cross and Major[13], to enable peer collaboration and assessment to take place. Another issue is the potential for peer assessment to be too time consuming and difficult to manage for large numbers of peer groups. There are a number of potential solutions to this and technology can offer benefits. This is discussed later.

In relation to peer assessment and collaboration in groups, there is the risk that ‘freeloaders’ can succeed without doing any work. That is, a freeloader who does not carry out their share of the work, or engage with the rest of the group, can be carried along and be unfairly supported by the rest of the group. This issue can be addressed in a number of ways; Tu and Lu[14] discuss their method for dealing with freeloaders.

Another issue of concern is the fact that the administrative process can be difficult and time consuming to manage. This is a key issue, since it can almost negate the benefits offered if it is too time consuming. There are numerous ways to engage students successfully in peer assessment, including the use of technology to deal with administration issues. Students may resent the potential for their grades or results to be dependent on other students. These fears can be resolved in ways which are discussed later.

Self assessment

Falchikov[15] discusses some of the benefits of peer and self assessment such as the learning benefits, critical ability, confidence and independence in individuals (self confidence). This study compares some similarities and differences between self and peer assessment. Peer assessment is the process of assessing one’s peers whereas self assessment is a self critique. There may be discrepancies if both are used in conjunction to award marks. One issue raised is whether self assessment is as valid as peer assessment. Some students are prone to over or under estimate their achievements when engaging in self assessment relative to their assessment of others.

Various studies demonstrate the benefits of self assessment, which can promote the ability of students to assess critically their knowledge and understanding. However, when it comes to assessing their own performance, students can have a different view from their peers. Li[16] discusses a potential problem in which self and peer assessment can skew grades. This is also discussed by Tu and Lu[14] who propose a way of resolving the issue. Dunning Heath and Suls[17] argue that the link between self assessment and actual performance is weak, claiming that peer assessment is a better measure of performance. Lejk and Wyvill[18] suggest that self assessment produces a wider range of scores and should therefore be excluded from grading.

Orsmond[10] reports on earlier research that provides conflicting evidence. Orsmond cites work by Falchikov and Boud[19] suggesting that there is no real tendency to over or underestimate performance. This suggests that including a self assessment mark with peer assessment does not have any real effect on grades. One thing these and other studies show, however, is that, as long as the assessment criteria are well designed, there tends to be a closer correspondence between student grading than between tutor grading. Therefore, despite potential differences in the way self assessment may support or detract from the overall peer assessment process, as long as it is properly designed and executed, students will benefit from it.

The social implications for peer and self assessment must also be taken into account. For example, students have to work with peers who they may not normally socialise with and many students find grading other students difficult. Topping and Ehly[20] discuss some of the social demands placed on students when engaging in self and peer assessment. Pope[21] also shows that self and peer assessment increases stress, but that it still leads to increased student performance.

Successfully embedding peer assessment in the curriculum

In order for peer assessment to be available for all students the process needs to be managed appropriately[2], which means including peer assessment explicitly as part of the formal academic programme. Bruffee[5] discusses this in further detail by highlighting how the ‘traditional’ academic format is designed more for information delivery in a lecture and not for promoting student interaction.

For peer assessment to be successful for both tutor and student, the process needs to be clearly defined early on, with roles and responsibilities laid out for all – including the tutor. Students need to appreciate the intended benefits of engaging with peer assessment and must be supported in developing effective collaboration. This includes support for critical and constructive peer assessment and on how to provide formative feedback. The tutor has to take responsibility for the process to ensure that it works; for example, to ensure that peers are matched appropriately, that enthusiasm for cooperation is fostered, and that social interaction is supported[8].

A wide range of methods for peer assessment are reported in the literature, which can be utilised to suit individual teaching preferences and goals. Barkley, Cross and Major[13] discuss assessment for collaborative writing. Another method cited by Topping and Ehly[20] is peer response groups where students gather together to provide feedback on each other's work. This not only promotes better understanding but helps improve social skills. Another approach is for students to comment on each others' reports. An example in organic chemistry is highlighted by Ivan et al[22]. There are numerous books giving ways of embedding peer assessment in the curriculum; for example Haines[23], Exley and Dennick[24] and Johnson, Johnson and Smith[4].

The important feature of peer assessment, however, is that it should assess the process of peer collaboration and not simply the product.

Peer assessment models

Probably most methods of peer collaboration could be used in a summative manner. However, it is this assignment of marks that makes summative peer assessment awkward, since individual tutors will have different preferences. The assessment models used have different strengths and weaknesses. The important feature of peer assessment, however, is that it should assess the process of peer collaboration and not simply the product. For example, if a group of students collaborate on a joint report, peer assessment should focus on how well the students collaborated and not simply on the report.

Lejk and Wyvill[25] review some of the main models commonly used for peer assessment. This review includes multiplication of a group mark by a weighting factor. This model was first proposed by Goldfinch and Raeside[26] and has since undergone some additional iteration, as reported by Li[16]. Another commonly used method is the distribution of marks: the tutor provides a set of marks for the group and the students divide the marks according to individual efforts and contributions to the work.

From these methods other models have evolved to meet the needs of different approaches to peer and self assessment. Johnston and Miles[27] describe a model in which students work on a group project and then submit individually. Marks are assigned and the authors acknowledge that in principle students can gain more than 100%. Another approach is taken by Margerum et al[28] whereby students are not only graded by their peers, but by their self assessment marks and, additionally, by further review in response to peer feedback on their original work.

The models predominantly focus around peer, self or a mixture of both and some take a holistic view or a structured approach using well defined weighting algorithms. In addition, the development of technological approaches to support peer assessment is also becoming more prominent.

Using technology to support peer assessment

A growing number of tools are now being reported that support peer collaboration and peer assessment. In the 1990s, when electronic communication started to become routine for undergraduate teaching, a range of 'standard' communication and other bespoke tools were utilised for peer collaboration and peer assessment. Rada[29] reports on three different approaches to foster peer collaboration and assessment using different electronic tools. Another system was developed for students to review and comment on each other's work[30]. Tsai et al[31] also report a similar tool aimed at allowing students to review each others' work online. Liu and Tsai[32] report more recently on a web based system for assessing students portfolios.

Yu et al[33] describe a web based system which was designed to meet various pedagogical underpinnings that support peer assessment. Students were able to pose questions, review and peer assess to support each other. Keppell et al[34] discuss the use of 'technology enhanced learning environments' to support peer assessment.

Peer learning and assessment facilitated through the use of Blackboard, a commercial Virtual Learning Environment, is reported by Chin[35]. Students work in groups on a project and use the VLE to communicate and share work with each other. A standard peer assessment form was used, where students grade the contribution of each group member to the project. Students submitted their marks via Blackboard. The author reports that students found the work enjoyable and beneficial and that the peer assessment scheme used was considered fair.

The Universities of Loughborough and Hull have a collaborative JISC (Joint Information Systems Committee) funded project to develop a peer assessment tool called WebPA (webpaproject.lboro.ac.uk). This web based tool currently provides support for peer assessment of large cohorts of students by automating the marking scheme. This marking scheme is similar to that developed by Goldfinch and Raeside[26] and further developed by Li[16]. Additional functionality being developed includes written peer feedback to make the tool more robust and one which can be used by any number of disciplines. WebPA is being developed as an open source tool which will be freely available.

Peer assessment in the sciences

Glaser and Poole[36] developed a web site focusing on organic chemistry which the students used to support their studies. Students were put into groups to undertake activities for which they had to produce reports. These reports were submitted and published on the course website. Students then had to review the reports of at least five other groups and submit feedback and marks to the tutor based on pre-defined assessment criteria. Student use of the supporting technology was mixed, but the authors found the overall experience was beneficial, especially for dealing with large cohorts of students.

students found the work enjoyable and beneficial and ... the peer assessment scheme used was considered fair.

Hass[37] has promoted student directed learning with peer assessment in the organic chemistry laboratory. Students were placed into groups to undertake ten experiments during the semester. For each experiment different students had to act as coordinators to lead the group. At the end, peer assessment was used to assess the contributions of each group member. Students undertook experiments in a traditional fashion, in parallel . The author found that there were no statistical differences between peer collaboration and assessment and traditional laboratories, but argues that the results are more qualitative. For example, with the collaborative approach, students seem more prepared for laboratory work.

Stevens[38] discusses a simple peer assessment process to help astrophysics students engage with a difficult topic of finding extrasolar planets. Students worked together in groups for the duration of the project and gave assessed seminars once the work was completed. Students then complete peer assessment forms to assess their group members on their contributions. The author reports that the students found the support of peers in working together towards a common goal beneficial to their understanding of this difficult topic.

Peer review of work is the basis of scientific publications. Venables et al[39] therefore felt this approach to peer assessment, where students would review each others' essays would be beneficial for students as a way of introducing them to the process of scientific writing. Student essays were blind marked; some students asked for their feedback also to be anonymous as they felt uncomfortable having to point out errors in essays. The authors found that the peer assessment process was intellectually stimulating and useful to the better understanding of the course material.

The production of student posters is a fairly common tool for presenting student work. Wimpfheimer[40] reports how student posters are often assessed by tutors, but reports on a process whereby the posters are peer assessed. Students present their posters and are given a standard peer assessment form to mark each other's work, including their own, since the author feels self assessment is important and increases the students' sense of ownership. The tutors use the same assessment form and their marks account for half the assessment, the other 50% coming from the peer assessment. The author argues that the quality of posters is high and helps students to understand better how to display information concisely.

Peer assessment has been addressed in the teaching of a calculus based class to engage students in the process of evaluating scientific information[41]. Students peer assess each other's weekly homework problems. To aid this process, students are provided with evaluation rubrics that have descriptors for each criterion. Criteria cover aspects such as physics content, relevant representations and problem-solving strategy. The question of whether peer assessment in this approach aids the learning process is discussed.

Glaser and Carson[42] discuss their intent to help students connect the content of their chemistry course to that of the real world, in a process which includes peer review. The authors developed a project 'The Chemistry Is in the News' to allow students to draw explicit connections between course content and real world issues. The project involves the study, creation and peer review of news portfolios by collaborative student groups. The news portfolios created by students are peer reviewed. The authors discuss some of the barriers to be overcome to make this project successful.

One difficulty of evaluating the effectiveness of collaborative work and peer assessment is whether they have any effect on final grades. An additional problem is the correlation of any potential gains in performance to any changes in activity such as peer collaboration and assessment. Wamser[43] suggests that peer collaboration shows a discernable increase in student grades. Students on a chemistry course can opt to take weekly peer led team learning (PLTL) workshops; the results seem to suggest that final grades are higher for participating students. The benefits of PLTL and the longer term impact on workshop peer leaders are further reported by Gafney and Varma-Nelson[44]. They find that there are significant and continuing benefits to learning.

The issue of peer and self assessment is addressed by Bedford and Legg[45] for chemistry and natural science students. Students were split into four independent teaching groups (each consisting of about 35 students). Each workshop focused on different approaches, including peer and self assessment and a control group. The authors found that the students favoured self and peer comments over comments provided by tutors.

Tribe and Kostka[46] report how student peer groups developed new experiments for other students in their class, which were based around student interests but linked to required curriculum teaching. This approach came about through feedback from students that they found existing laboratory manuals difficult to understand. Peer review and feedback was provided by students undertaking the experiments, and knowing that they were 'teaching' their peers gave the groups added motivation.

Wenzel[47] provides some useful references relating to the use of self and peer assessment. The author also describes some tools to guide student peer and self assessment of group activities for laboratory work. One approach to peer evaluation is to provide open ended questions as guidance for students to respond to. It also suggests that feedback from someone in an 'instructional capacity' (laboratory demonstrator or tutor perhaps) can help students interpret the peer and self feedback. The author reports that they have used several of the tools and that students find peer and self assessment of laboratory work useful.

The literature over the years shows that there are clear educational benefits from the adoption of peer learning and assessment schemes. With increased student numbers and greater pressures on curriculum time, developments in peer assessment have kept pace to remain effective in the modern educational setting. Adoption in the physical sciences is no exception, with peer assessment schemes being used in a wide range of contexts. These include alternatives to the traditional tutor marked methods for laboratory work, scientific group projects and student poster presentations.

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Implementing Physics Education Research to Inform and Enhance Pedagogical Approaches

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Abstract
Since 1999 the School of Physics in the Dublin Institute of Technology has been critically analysing its pedagogical strategies, leading to a reconsideration of teaching, learning and assessment practices. In 2001, the Physics Education Research Group was established to develop, implement and evaluate pedagogical initiatives in physics education and to undertake rigorous education research studies to inform and evaluate these developments. Various innovative pedagogical approaches including problem-based learning, project-based learning, peer instruction and eLearning have been implemented. These pedagogical developments were informed by education research studies which examined student learning, lecturers' conceptions of learning and teaching and group interactions and dynamics. Further education research studies are continually carried out to evaluate all pedagogical approaches in order to enhance and continually improve the students' learning experience. These studies, which include both qualitative and quantitative methods, are conducted primarily using phenomenography, action research or evaluative research approaches.

Introduction

Over the last fifteen years significant changes in student profile, stemming primarily from mass education and dramatic changes in information technology, have led to the scrutiny of the suitability and appropriateness of teaching practices in higher education[1]. The effects of the changes in student profile have arguably been most acutely felt in physical sciences education due to the dramatic decrease in the number of students choosing to pursue science in undergraduate studies (IOP Report, 2001[2]; Task Force Report, 2002[3]). In 1999, in the context of Irish higher education, the drop in student applicants meant that new entrants to physics programmes tended to have less physics knowledge and were not as motivated as students in previous years, which in turn led to poor attendances in lectures and high dropout rates. This put pressure on physics educators to not only recruit students but also to motivate and support the students in order to improve retention rates.

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Since 1999 the School of Physics in the Dublin Institute of Technology (DIT) has been critically analysing its pedagogical strategy, leading to a reconsideration of teaching and assessment practices that has manifested itself in a push towards student-centred learning and an acknowledgement of the importance of lifelong learning skills. This move, which has been informed by education research, with its emphasis on theory and practice, and physics education research, with its emphasis on the how students learn physics and develop conceptual understanding[4], has led to the introduction of many innovations that promote student-centred learning as physics lecturers not only take a critical look at what is being taught but also how it is being taught. This has led to awareness, among staff, of the importance and potential of student-centred and active learning, and specifically, to the development and introduction of a physics problem-based learning course in 2001.

Although many of the reasons for changing to problem-based learning were primarily pedagogical, another factor was the increased importance that industry was putting on the key skills whose development is inherent in the problem-based learning process. Also, the effects of fewer students choosing to pursue physics at all levels of education had lead to a reduction in students' academic qualifications entering the physics programmes which in turn led to the problems mentioned above and caused difficulties in maintaining the academic standard. The problem-based learning course was developed to address these problems and make the subject more appealing to entrants. However, in changing the whole approach to teaching and learning, it was important to ensure the course standard and quality was maintained. The primary benefactors of this innovation had to be the students, and its success had to be measured in terms of their learning and learning experiences. Therefore the problem-based learning staff team developed an evaluation strategy that concentrated on the students, their knowledge and their skill-based learning outcomes[5]. The project to develop, implement and evaluate the problem-based learning course was the first of many significant and rigorous physics education research projects undertaken within the School of Physics.

Establishment of the Physics Education Research Group
To undertake the development, implementation and evaluation of the problem-based learning course, in addition to other research projects to inform curriculum development and teaching and assessment practices, the Physics Education Research Group was set up in 2001. The main areas of research were, and still are, the development, implementation and evaluation of new and appropriate teaching and assessment strategies, studies of student learning and misconceptions, evaluation of the effectiveness of different learning resources and teaching methodologies and the development of learning resources to enhance student learning.

The research undertaken by this group is heavily informed by previous education research studies for although physics education has remained relatively unchanged for over fifty years[6,7] there is an abundance of physics education research literature. Many of the studies reported in the literature have examined the effectiveness of the traditional pedagogical approaches within physics education and reported many shortcomings. These approaches tend to be teacher-centred and for the most part, the priority within a physics course is to transmit the 'correct' information to the students[7]. The shortcomings of these approaches, as revealed by physics education research, have become more apparent with the changes in student profile, due to such things as mass education, diversity, competition and information technology[8]. One possible cause may lie in the suggestion that traditional physics education tends to assume that systematically and repetitively solving simple algorithmic problems will develop an understanding of the physics concepts and principles, as well as an appreciation of the role they play in solving problems[8,9]. This is evident in the way standard physics textbooks are presented (e.g. Young et al[10]). Research findings have demonstrated that problem solving by itself does not develop a deep understanding of concepts and principles, even though some students can often become proficient problem solvers by developing the ability to solve these problems through recognition of when to use an appropriate equation[8,11-13]. Many studies have revealed that students, who could easily solve standard textbook problems, were often unable to relate the results to other, more complex situations[14].

Another shortfall of traditional physics courses arises from the tendency to teach with the attitude that students are 'blank slates'. Students are 'given' the information and are then required to repetitively solve problems in order to develop conceptual understanding. However, results from physics education and cognitive research show that students begin a physics course with their own conceptual framework, developed either through their own experience of the world or through *common sense*[7,15]. The conclusion drawn from much of this research is that physical science educators need to provide a learning environment that encourages the construction and reconstruction of knowledge and understanding[4].

In summary, there appears to be an obvious contradiction in traditional physics education. Two of the principal goals of a physics programme are to develop conceptual understanding and problem-solving skills, but to achieve this students are 'given' the information and then repetitively solve quantitative problems[7]. However, education research has shown that the students do not develop conceptual understanding from solving these problems and furthermore they cannot develop as adept problem-solvers because they don't have the conceptual understanding. These realisations have led to a growing awareness of the need to move towards more student-centred learning approaches informed by the constructivist learning theory. Research by Angell el al[16] has suggested that if physics education is to prepare physicists for 'tomorrow's society', it should be characterised by more student-centred learning approaches and a stronger emphasis on knowledge in context.

The purpose of the Physics Education Research Group was to learn from, and build on, this research to develop appropriate student-centred learning environments. It is a central goal of the group to ensure that within these learning environments the students move away from rote and surface learning to a more constructivist learning experience within which they can develop their conceptual understanding and problem-solving skills. Every aspect of each of the pedagogical approaches was informed by previous education research and physics education research, and in addition the processes of change, development, implementation and evaluation were rigorously researched as they happened, and continue to happen, by the Physics Education Research Group.

In the following sections, the research methodologies and methods used within the Physics Education Research Group are described. In the subsequent sections, three pedagogical approaches are described along with the research studies that have informed their development, implementation and enhancement.

Research Methodologies and Methods
The Physics Education Research Group uses the following research methodologies:
- Phenomenography
- Action Research
- Formative Evaluation

Phenomenography is an empirical research methodology that was designed to answer questions about thinking and learning, especially in the context of education research[17,18]. It is concerned with the relationships that people have with the world around them and aims to elucidate the different possible conceptions that people have for a given phenomenon. Phenomenography is sometimes seen as a subset of phenomenology[19] but interestingly, phenomenography was not originally derived from the phenomenological philosophy[20] nor did it emerge or derive from phenomenology[21]. In the phenomenographic approach the objective is to find the qualitatively different ways of experiencing or thinking about the same phenomena[22]. It assumes that there are a limited number of qualitatively different ways in which different people experience a certain phenomenon[17,22]. For instance, Bowden et al[13] used this research methodology to investigate students' understanding of displacement, velocity and frames of reference. Sharma et al[23] also adopted a phenomenographic methodology to describe the variations in the way in which students understood the concept of gravity. The Physics Education Research Group uses this approach to examine students' conceptual understanding and problem solving abilities[24,25], as well as lecturers' conceptions of learning and teaching[26]. The findings from these research studies have informed the development and facilitation of the various pedagogical strategies.

The problem-based learning initiatives were designed, implemented and evaluated through a collaborative action research project[5]. Action research is "any systematic inquiry conducted by teacher researchers to gather information about the ways that their particular school operates, how they teach, and how well their students learn"[27]. All the pedagogical approaches are formatively evaluated in order to continually enhance and develop different aspects of the courses including assessment[28], facilitation, resources and scaffolding.

Research Methods
Although different research methods have been used within the research studies, the dominating method has been the *open and deep interview*, which is carried out in a dialogical manner[29] and always recorded and transcribed before being analysed. However, other methods include:

- Pre and Post Qualitative Tests (Concepts Tests)
- Pre and Post Quantitative Tests
- Questionnaires, surveys and inventories
- Observations

The pre and post concept tests have included the Force and Motion Conceptual Evaluation (FMCE)[30], the Force Concept Inventory[31], the Mechanics Baseline Test[12], the Heat and Temperature Conceptual Evaluation (HTCE)[32] and the Thermal Concept Evaluation (TCE)[33]. As many of these inventories were developed within the context of the American education systems it was first necessary to validate them within the context of the Irish education system and make adjustments where appropriate. The validation process involved administering the inventory to a small number of students followed by interviews in which the level of their conceptual understanding was ascertained. In certain instances, customised concepts tests were developed to ensure suitability in a given context. Pre and post quantitative tests were also developed which included questions that ranged from 'end-of-chapter' type questions to open context-rich questions. Other tests were developed that were both quantitative and qualitative in nature but examined a specific area of physics or set of skills. For instance a test was developed to examine the development of laboratory knowledge and skills.

Other inventories are used to examine students' attitudes to physics, expectations, approaches to learning and learning styles, and lecturers' approaches to teaching (Approaches to Teaching Inventory)[34]. As with the concepts tests, when using inventories that were developed in a different context it is necessary to ensure that they are valid with the context of the research. It should also be noted that these inventories are used as one research method within a myriad of research methods in a triangulation process. Questionnaires and surveys are also used to obtain the students perceptions, feelings and opinions relating to particular aspects of the pedagogical approaches, such as the assessment strategy, the learning activities and resources and the facilitation. Observations, which are recorded, are used to study group dynamics, and norms, and the learning process within the group environment. Through rigorous discourse analysis of the group interactions and outcomes, it is possible to study and analyse the ways students learn, create meaning and reconceptualise their knowledge. The purpose of all these research methods is to obtain data which when analysed will inform the teaching and learning practices within the School.

Although new pedagogical approaches have been introduced ... many of the modules are still taught through the more traditional education methods of didactic lectures, standard tutorials and practical-driven laboratories.

Pedagogical Approaches
Although new pedagogical approaches have been introduced within the School of Physics, many of the modules are still taught through the more traditional education methods of didactic lectures, standard tutorials and practical-driven laboratories. Many of the research projects examine the benefits and shortcomings of these learning activities with the purpose of making enhancements and informing the change to the new pedagogical approaches. While eLearning is used extensively throughout many modules it will not be discussed here as both the traditional and new pedagogical approaches are now supported, to different degrees, online. An on-line learning resource centre was developed, which includes online tutorials, assignments, of quizzes, individual students' feedback pages, calendar, noticeboard and details of the laboratory programme. In the problem-based learning course, the feedback from both the formative and summative assessments is provided through the online site[28]. The students are also required to complete regular online multiple-choice quizzes as part of the overall continuous assessment.

In the following sections the traditional education approach and three of the new pedagogical approaches that have been introduced are described along with the research that has informed their development, implementation and enhancement.

'Traditional' Education
The Physics Education Research Group has conducted a number of research studies that have examined the effectiveness of different elements of the traditional education approach. In particular, one study investigated the development of students' conceptual knowledge in core areas of physics and their problem-solving abilities[24,25,35]. The research methods used were the pre and post concepts tests and the open deep interviews. One of the findings from the study demonstrated that students entering third level education have little or no conceptual mechanics knowledge, regardless of whether they had studied physics in second level (within the Irish education system). The study, which involved approximately 600 students from two different higher education institutes, also revealed that the vast majority of students' conceptual understanding remains relatively unchanged after formal instruction in mechanics at higher level. The study also showed that the majority of students do not approach problem solving in a strategic or scientific manner. Most of the students use a 'plug-and-chug' approach by identifying variables and trying to find some formula, appropriate or not. Many of the findings from this study provide the rationale for the change to more student-centred approaches such as problem-based learning and peer-instruction. It also provides a benchmark against which to measure the success of these new pedagogical approaches.

> *Another ... study is examining ... traditional laboratory practices with the purpose of identifying deficiencies which can be addressed through ... improved structures, resources, experiments and laboratory assessments.*

Another ongoing research study is examining the effectiveness of traditional laboratory practices with the purpose of identifying deficiencies which can be addressed through the introduction of improved structures, resources, experiments and laboratory assessments. The study examines students' competences in different aspects of the laboratory, such as tabulating data, drawing and analysing graphs and calculating uncertainties. This study, which is on-going, is also informing the move towards more project-based laboratory practices.

Another ongoing research project is examining the traditional students' perceptions of physics and approaches to learning. The purpose of this project is to compare the effects of different pedagogical approaches on the students' views' of physics and on how they learn.

Problem-based Learning
Problem-based learning is now used as the sole pedagogical approach in physics within the first year of four degree programmes (Physics Technology, Science with Nanotechnology, Physics with Medical Physics and Bioengineering, and Physical and Life Sciences). It was chosen as a pedagogical model as it was felt it could address the problems outlined previously and make the subject more appealing to entrants. The contextual, group-based and experiential learning elements of the approach instill the motivation required for the students to adopt a deep approach to their learning and encourage them to take more responsibility and independence in the learning process. In this way, this approach better supports the development of the students' conceptual understanding and problem-solving skills. The problem-based learning team felt that the purpose of introducing this initiative was not only to help students develop an understanding of the conceptual nature of physics but also to support the development of the skills and competences associated with being a physicist. The problem scenarios focus on key concepts and enable students to develop problem-solving abilities and to become competent in applying their knowledge to solve problems. However, there are also traditional tutorials integrated into the process to allow for learning through cognitive apprenticeship and repetitive exercises.

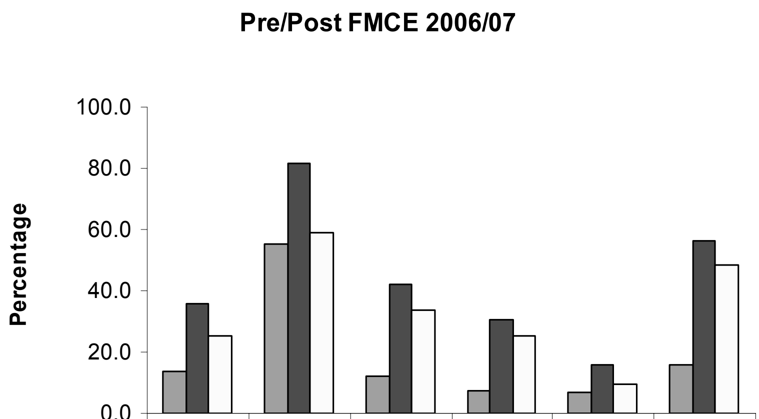
An induction programme for students was developed after which the first year physics syllabus is covered by approximately 25 problems which are 'real', engaging, place the group in a 'professional' role, and require the students to make assumptions, approximations, and deal with omitted information. After a few problems the students become more aware of their roles and of the expectations the tutors have of them as individuals and as group members. The group is continuously assessed and the students are given regular feedback. A complete set of assessment criteria for the group process was developed at the outset, and includes such factors as the individual level of contribution, peer-teaching, questioning and completion of group-assigned tasks[28]. Collaborative assessment is introduced about halfway through the academic year after negotiation of the assessment criteria. From this point on, after each problem each student is required to self-assess their own contribution to the group process[28].

All stages of the development and implementation of the problem-based learning course have been informed by research studies carried out by the Physics Education

Research Group. Indeed, the course itself was developed, implemented and evaluated through collaborative action research[5,36,37]. This research provided valuable information after one year of the course so that substantial changes could be made to the structure of the course and the assessment methods and criteria. The research methods used within this research study were student evaluations, concept tests, quantitative tests, interviews and focus groups.

The change from traditional teaching to problem-based learning met many challenges and obstacles, least of which was the reluctance of a substantial number of physics staff to get involved in, or even support, the initiative. In order to devise strategies to support the change, the Physics Education Research Group undertook a research project which set out to investigate the implications that physics lecturers' conceptions of teaching and learning may have for the use of problem-based learning in physics education[26]. Previous research had shown that if problem-based learning is to be successfully implemented it requires lecturers who use student-focused teaching approaches and have student-focused conceptions of teaching and learning. This research studied the teaching approaches currently used by physics lecturers in departments where problem-based learning courses had been introduced and examined their conceptions of teaching and learning. It examined the approaches and conceptions of both the lecturers involved in these courses and the lecturers with no involvement, as well as those opposed to the use of problem-based learning. Specifically it determined the relationship between the lecturers' conceptions of teaching and learning and their perceptions of problem-based learning and the relationship between their perceptions of the teaching contexts and the teaching approaches they adopt. The research revealed only a minority of the physics lecturers currently have compatible student-focused conceptions of teaching and learning. However, this study also revealed that the majority of lecturers' conceptions of teaching and learning, and hence their teaching approaches, are affected by their teaching contexts. Many of these lecturers do not feel their current teaching contexts are appropriate to support the use of student-centred learning approaches. Therefore if the lecturers with compatible conceptions of teaching and learning introduce the new pedagogical approach, there are many other lecturers who might be persuaded to get involved, if they perceive their teaching contexts are appropriate. The research findings provided possible explanations for the shortcomings of traditional education as identified by previous education research, particularly in terms of the development of conceptual understanding and problem-solving skills. As conceptual understanding is not something that is seen as a priority and it is perceived that problem-solving skills are developed adequately with current pedagogical practices, many lecturers do not see the need to change to student-centred learning approaches such as problem-based learning.

Similar to the study within the traditional education approach, research examined the development of students' conceptual knowledge in core areas of physics and their problem-solving abilities within the problem-based learning course[25,35]. Again, the research methods used were the pre and post concepts tests and the open deep interviews. Unlike the students within a traditional education environment, the problem-based learning students showed a substantial increase in their conceptual understanding after completing the course. The findings from this study also highlighted areas where improvements were necessary. For instance, when the FMCE was used to examine students' conceptual understanding in mechanics it revealed there was little gain in their understanding of Newton's third law. Figure 1 shows that pre and post test scores from the FMCE along with the percentage gains. It should be noted that the gain is expressed in terms of what Hake defines as the normalised gain, which is the average increase in students' scores divided by the average increase that would have resulted if all students had perfect scores on the post-instruction test. When the problem-based learning tutors were made aware of the findings and reviewed the set of problems they realised that Newton's third law was not explicitly dealt with.



	Overall	Velocity	Accel	Force (1,2)	Force (3)	Energy
Pre-%	13.9	55.2	12.3	7.6	6.9	15.6
Post-%	35.7	81.5	42.0	30.7	15.9	56.5
Gain-%	25.33	58.75	33.90	25.05	9.67	48.47

Figure 1: FMCE Results from Problem-based Learning Students 2006/07

Peer Instruction
Within programmes and modules where the introduction of problem-based learning was not feasible the Physics Education Research Group looked at other ways of facilitating a student-centred learning environment within a traditional lecture-based environment. The group felt that many of the weaknesses of the traditional lecturing system could be addressed by using Peering Instruction (PI)[38,39]. This is a widely used pedagogy in which lectures are interspersed with short concept questions designed to reveal common misunderstandings and to actively engage students in lecture courses. Using the PI approach,

the lecturer starts the lecture with a short introduction of the topic and then presents a concept question with four possible answers. The students are asked to vote individually on which answer they think is correct and their level of confidence. The students are then put into small groups and asked to convince their peers that their answer is correct (peer instruction). The students are then asked to vote again on the answer. The lecturer then explains the correct answer after which another concept question can be posed that examines the same concept. If the voting results show that there is still some confusion on the topic the lecturer can spend a bit more time on the confusing issues. The voting system can be by a show of hands, flash cards or computerised voting system (Classroom Response System). However, the show of hands and the flash cards tends to be very inefficient and harder for the tutor to facilitate. There are also problems with students not putting up their hand or card for any answer or putting it up for more than one answer. The PI approach has been widely used in the United States and has been largely championed in the area of physics by Eric Mazur[38,40]. Mazur and others (Fagen et al[40]) have shown that peer instruction is applicable to large lecture groups (up to 250 students) and they have shown that the measured gain (using pre and post tests) in students' understanding is on average 40%, which is far higher than students attending traditionally taught courses.

project-based physics laboratory work can improve students' understanding of physics concepts

Published research[38,40] has shown that PI can significantly enhance the learning experience for students. The results show that attendance improves and what is more, attention and student involvement increases. The tests show that this teaching style engenders a better understanding of the fundamental concepts and discourages a number of bad study habits such as rote memorisation and exclusive focus on problem solving. Mazur reports that the students' energy and enthusiasm during the discussions are contagious. He also claims that once one has experienced it, it is difficult to revert to lecturing to a passive and mostly silent audience.

Peer Instruction has recently been introduced into a number of modules within the School of Physics and researchers within the Physics Education Research Group are currently evaluating the process in terms of student learning and determining effective and efficient ways in which the process can be facilitated. This research project entails taking one module, Nuclear Physics, in which PI has been introduced and evaluating its success in terms of students' attendances, motivation, interaction and learning. As in the research studies mentioned previously, pre and post concepts test are used to determine the levels of learning.

Project-based Laboratories

When the problem-based learning course was initially introduced all the theory part of the course was taught through problem-based learning but the laboratory kept the traditional first year practicals, workbook and assessment criteria. Evaluation of the laboratory sessions showed that the students felt that the laboratories were inconsistent with the educational philosophy of the rest of their course. A decision was made to expand the problem-based learning philosophy into the laboratory. Experiments were designed in such a way that they became projects for which the students had to work in groups and were only given an objective and a list of equipment available in the laboratory. Each group has to write a proposal explaining how they intend to reach the objective or solve the problem. The students are assessed on their proposal, laboratory logbook, group work, and end of project report. A pilot research study was undertaken to compare the conceptual understanding of students' working in the project laboratory, to those working in a traditional physics laboratory. This preliminary study indicated that project-based physics laboratory work can improve students' understanding of physics concepts[41]. It also revealed that students learning through these laboratories have a stronger awareness of their learning and the skills they develop than their traditional counterparts. A more extensive study has recently been undertaken and the data is currently being analysed in order to make enhancements to this approach.

Conclusions

In recent years one dramatic change in Higher Education that has occurred is the move towards the use of a more 'student-centred' approach. The motivation and rationale behind this move to student-centred learning has been driven and informed by extensive education research studies that have examined how students learn and what factors determine the quality and type of learning. Student-centred learning pedagogical approaches require the active participation of the students and involve scaffolding and supports to allow students to construct their knowledge and understanding. In the School of Physics in the Dublin Institute of Technology, this move towards student-centred learning has been informed by education research and specifically physics education research. In addition the processes of development, implementation and evaluation have been extensively researched by the Physics Education Research Group. This group has conducted rigorous research studies to ensure that the new pedagogical approaches are successful by identifying shortcomings and maximising the benefits. Research has been carried out which looked at the process of change itself and examined student learning and development in order to inform teaching, learning and assessment practices.

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An introduction to communicating science

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As the media have become more pervasive, complex and fragmented, scientists are at greater risk than ever before of losing the trust of their audiences, unless they engage with the media.

Abstract
It is becoming increasingly recognised that students in Higher Education must acquire the skills necessary for professional and personal development, as well as for academic progress. The media have recently focused on the issue of declining public interest in the sciences and the lack of accurate reporting of science. We have developed a new programme, which endeavours to address both issues involving a three day intensive course covering writing, TV and radio. In addition to the targeted activities of learning the skills of science communication, the programme encourages partnerships, and exploits the resources and expertise available from various institutions. The undertaking of this type of programme is not limited to the acquisition of time slots in a studio such as Bush House. Most university campuses are now home to their own recording studios and even have television facilities. However, the programme requires only a video camera and audio recording equipment. The success of this science communication module and of two others run by MOAC and CBC (Team Development and Decision-making and Leadership) has encouraged us to develop a complete postgraduate certificate in transferable skills. We anticipate the certificate will be a valuable vehicle for consolidating and enhancing the training discussed in this article.

The General Skills Problem
It is becoming increasingly recognised that students in Higher Education must acquire the skills necessary for professional and personal development as well as for academic progress. This recognition has arisen from concerns regarding the lack of preparation graduates have for embarking upon a career outside of their particular course of study. Employers, both within and outside academia, now demand that Higher Education Institutions place more emphasis on training in transferable (or generic) skills and interpersonal development. The report of Sir Gareth Roberts' Review for HM Treasury particularly points out that "[..] the skills profiles of many jobs within business have altered, requiring greater breadth of skills and aptitudes."[1] Higher Education Institutions are currently attempting to confront this concern across the board with the development of transferable skills and vocational programmes.

At postgraduate level, the demand for high quality PhD graduates in the sciences has also moved beyond scholarship alone towards a more comprehensive standard of education: employers are looking for balanced skills and aptitudes in a broad educational spectrum rather than focusing on specific and narrow scientific achievement. PhD graduates increasingly require a wide range of transferable skills in order to be successful in the employment market. The Joint Skills Statement [2] published by the UK Research Councils, the Arts and Humanities Research Board and PhD funding charities outlined a framework for skills development in Higher Education. These included, alongside research skills development: personal effectiveness, communication skills, networking and team-working.

The Communication Problem
The media have recently focused on the related problems of declining public interest in the sciences and the lack of accurate reporting of scientific information to the public. It seems evident that in the absence of accurate and clear reporting, the public interest in scientific issues will be reduced, and this loss of interest will result in a reduced incentive on the part of the media to report on such matters. If scientists are not trained to report to non-scientists clearly and accurately on scientific issues, it will be difficult to break this cycle of decline. This lack of training in media-related issues has meant that scientists are unprepared to discuss their research and its implications. As the media have become more pervasive, complex and fragmented, scientists are at greater risk than ever before of losing the trust of their audiences, unless they engage with the media.

The BBC pointed out in an online report that experts had made a range of recommendations for improving public understanding of scientific issues. These included: (i) media agencies employing more science graduates, and (ii) encouraging science graduates to take part in media training.[3] In addition, the Wellcome Trust has been highly vocal on this subject. They commissioned a survey regarding scientists' perception of science communication. The results of the survey revealed that in the opinion of scientists "… the things that would most help to improve communications between the general public and scientists were encouragement and incentives from institutions and funders (for scientists) to spend more time on science communication, (to have) training in dealing with the media, and (to have) more financial support."[4] A summary of their research also pointed out that "[..] fewer than one in five [scientists] have had training to deal with the media and/or to communicate with the public."[5] This deficit in communication between scientists and the general public is thus, among other things, attributable to a lack of incentive and resources in higher education, leading to a lack of confidence and awareness in graduating students.

However, professional scientists are now being encouraged to heal this breach through courses in communication, such as those currently run by the BBSRC [6] and the Royal Society's Media Programme.[7] Since the early 1990s, the agenda has shifted from public understanding of science to public engagement with science. Public engagement is now a focus of scientific organisations and higher education institutions and research councils, and scientists at all levels are being encouraged to take responsibility for communicating their research.

The onus on graduate training programmes is on training the scientists of the future. It is, therefore, the responsibility of the higher education institutions to offer their students the support, training and opportunities to develop their communication skills and their ability to encourage and respond to public and media interest in their work. These skills have now become a priority for professional development and the new generation of scientists must be able to engage more efficiently with an increasingly demanding audience. However, there is not a long history of tailored training programmes for young scientists. The question is how to develop such programmes so they integrate into existing postgraduate training and to ensure their relevance to students whatever their planned career path.

Skills Training at Warwick and Imperial

The Doctoral Training Centres (DTCs) are sponsored by the Engineering and Physical Sciences Research Council (EPSRC) which is responsible for the establishment of the Life Sciences Interface (LSI) Programme, in which the emphasis is very much on an innovative and comprehensive approach to postgraduate training. The EPSRC is focused upon building an effective research community out of the many developing LSI DTCs. The Doctoral Training Centres of the University of Warwick and Imperial College are multidisciplinary scientific training programmes at the interface between Chemistry, Biology, Physics, Mathematics and Computer Science. However, as Doctoral Training Centres, their responsibility to students' development does not end at challenging their scientific minds, but requires them to encourage and expand their ability to face unfamiliar situations with confidence and alacrity. Their very nature as programmes spanning multiple disciplines lends itself to the potential acquisition of manifold skills both within academic scientific practice and beyond.

The MOAC (Molecular Organisation and Assembly in Cells) Doctoral Training Centre at Warwick and the Imperial College CBC (Chemical Biology Centre) have taken a leading role within this community in developing transferable skills training for students within this pioneering scheme. In doing this they have had certain advantages, primarily those of being new (and hence being able to establish new ground rules), of being provided with funding earmarked for skills training and having staff who, from the outset, have been committed to the delivery of such training. Moreover, Warwick and Imperial have reputations such that they are able to attract outstanding students from the UK and around the rest of the world. These students are not only extremely able but are committed to launching their careers using whatever help and training their DTC can provide. They are intrinsically, therefore, an ideal cohort with which to develop a creative and effective skills training programme which may be used as a model by other centres. As small centres MOAC and CBC can take advantage of being able to build personal relationships with each and every one of their students and to track their progress closely throughout their time with them.

The outcome is that a transferable skills training programme has been implemented which owes nothing to the 'two hours a week in term-time' model, but integrates the acquisition of the different skills into the daily research lives of the students. It is during their routine research activities that students achieve both academic discipline and specialist knowledge in their chosen areas, and also personal development, enhanced communication skills, networking capabilities and team-working practice: these transferable skills are integral to their daily experiences.

This combination of excellent students and an active skills programme integrated into their research activities provides an unparalleled opportunity to address the problem of presenting scientific issues to the public. As part of their transferable skills programme we set up a science communication training project which involves all of our second year PhD students. This project introduces them to a greater awareness of current topical issues surrounding science for the public and in the media, in order that they may disseminate their knowledge and relate their practice to aware and active listeners. A criterion for the project was that it should relate to their lives as research students and should develop their skills in presenting topical and controversial issues to the public. It was structured as a three day venture held in London in January 2006, run by Gareth Mitchell, a lecturer at Imperial College's Science Communication Group, and presenter of the BBC World Service technology programme 'Digital Planet'. The programme is set out in Table 1. It will be run again in July 2007 for the following year's intake of students.

The CBC/MOAC Event

The event began with an introduction to science journalism. In an interactive class session, the students encountered and discussed a range of science issues from that week's news. This included pieces from newspapers, television, and radio.

Next the group turned its attention to communicating science through television in Imperial College's own TV studio. Students had the opportunity to conduct an 'as live' television production in the style of the BBC's 'Question Time', involving one presenter and three guests. With the help of technical support experts from the Media Services team at Imperial College, individual students took up the positions of director, camera operators and vision mixers. Stem Cell Research was the dominant topic for the students as they had been required to prepare this in advance of the event. The opportunity to conduct a simulated television debate engaged the students with dialogue relating to the ethical implications of current scientific research and the topical issue of the peer review process. The experience was enriched by giving students the opportunity to explore a mode of communicating science seldom seen on television. In so doing, they gained interesting insights into the nature of science controversy and began to explore and critique the manner in which science is reported in the broadcast media.

Figure 1: Studio

The second stage of the course involved an introduction to the medium of radio. In their novel guise as radio reporters, the students were instructed in the use of professional microphone and audio recording technology in order to conduct interviews and gather sound bites for their radio programmes. The first group involved themselves in current student politics at Imperial, with the issue of the implementation of a mandatory display of ID cards, which had provoked a strong reaction among students. They also managed to secure an interview with Professor Alain Gringarten, the Chairman of Petroleum Engineering and Director of the Centre for Petroleum Studies at Imperial College. The second group were slightly more ambitious in their endeavours and waited outside of the Houses of Parliament in the hope of catching an MP. However, despite their valiant efforts, the parliamentarians eluded them – no doubt a difficulty arising from the fact that it happened to be a Friday afternoon.

That evening, the two groups made their way to Bush House, the headquarters of the BBC World Service. They worked in studio S6 – a studio fully equipped for radio news and drama – and after editing their collected materials, they conducted a simulated 'live' broadcast under the expert supervision of the Studio Manager Simon Morecroft. The emphasis was particularly on public interest pieces, with the first group's broadcast discussion entitled "Is Britain about ready for an oil change?" tackling the current topic of the impending peak-production of fossil fuels. This was followed by a short debate on the matter of ID cards at Imperial College and the implications should this become a national phenomenon, entitled "Is Big Brother watching you?" The production finished with a light-hearted piece analysing the ethical implications of cloning Schrodinger's cat, a humorous experiment in quantum mechanics: "If a cat is cloned in a box and no one is around to see it, does it still meow?" with telephone guest speaker, physicist Alexis Rutherford.

The second group began with "The hot topic of global warming" followed by a piece on "The explosive issue of nuclear power". Also topical that day was the issue of the bird flu, discussed in the context of the potential impact of the virus, should it reach the UK. In a gesture particularly relevant to the role and purpose of the transferable skills programme itself, the third item was a discussion about the problem of lower student interest in the sciences at high school level leading on to university. MOAC's own Professor and Centre Director, Alison Rodger, was on hand to discuss this worrying endemic deficit in students participating in and enjoying academic science. The topic is of concern to educators in scientific disciplines, and a major reason for programmes such as this one, focused upon bringing science back into the public eye.

At the end of the event MOAC and CBC provided feedback to the whole group of students who undertook the activity. The groups were given praise and/or criticism regarding their own group performances on the day and in their follow-up work.

Evaluation of the event

Meetings of the staff involved in the venture took place after the course was completed in order to evaluate the efficacy of the module.

a) Staff evaluation

Although running for the first time the module was felt to be a success. It was devised as an innovative approach to familiarising the students with the necessity of public interest in the sciences, as well as introducing them to the skills needed to cope with and indeed seek media exposure for their work. It was something that the students had never confronted before, and offered them training in something totally removed from the laboratory, whilst still relevant to their discipline. The science communication programme opened up avenues that many had perhaps never considered, and some students have since expressed their interest in careers in scientific journalism. Others who remain focused upon a laboratory-based career gained invaluable experience and knowledge.

At the outset it seemed rather ambitious to fit so much into a short course, especially as for most of the students the broadcast environment was an unfamiliar one. However, the course organisers and the participants were pleasantly surprised at how well the doctoral students engaged with such a challenge. Communication skills have been enhanced by not only revealing the opportunities which are available to the students but also by improving their confidence in their own ability to discuss and share their work with others. Teamwork and cooperative skills have been tried and tested in an unfamiliar environment and students have applied their already strong problem-solving skills to something other than their own scientific projects. The proof of the module's effectiveness is given by the activities of the students since the course. Table 2 summarises the participants' public engagement activities in the 12 months following the module. One student's work has been discussed on BBC Radio Five Live, the national news and sport network. Others have been into school class rooms, worked on general public science displays of various kinds and, perhaps most importantly, all have talked with new confidence and effectiveness to their friends, families and members of the general public they have met in non-professional contexts. Some of them have created opportunities; e.g. by issuing a press release on a published paper, which led to an article in the Coventry evening Telegraph.

Figure 2: Editing

b) Student comments
Each student felt that, even if they were not interested in pursuing a career in scientific journalism, they would be more positive about being interviewed about their work or getting involved in publicity relating to their disciplines. Their post-course activities (summarised above and detailed in Table 2) show that this is not simply post-course enthusiasm.

In addition, their own suggestions from the evaluation forms were discussed, and we indicated which suggestions we intended to adopt, so they could see that their input was taken seriously. Some students suggested that there should perhaps have been more on written journalism, while others felt that they would have benefited from an extra tutor on the science communication training course who could have provided more criticism about their productions, more exercises and a brief written summary of what they had learnt during the day. We are implementing these changes for 2007.

Changes to the Event
Having now run this course once it is felt a number of improvements could be made. A structured follow-up to the course would be of great benefit in order to consolidate students' learning and monitor their progress, and would perhaps reveal opportunities which might otherwise be overlooked. In practice, not all students exercised their new skills, so a formal follow-up process would be valuable. Keeping track of the developing opinions of attendees who completed the programme may also prove useful in order to gauge to what extent they have found their additional learning useful. A review six months after the course from each student who attended, detailing in what ways they have used their new skills or knowledge has been implemented in order to assess the long term benefits of the course for their academic and professional development. Our policy has been for no formal assessment to be required for our transferable skills programmes, but a formative assessment or feedback would help us to improve what we provide.

As noted above, the students felt that communication in the sciences should be extended to include a course in scientific writing for journal publication. In a recent report on transferable skills in postgraduate education, Margaret Cargill pointed out that "[..] professional written skills form an important subset which contributes to many other skills categories. Skilled writing is an essential requisite for both academia and the workplace so intrinsic motivation for developing the required skills is high[..]"[8] It also contributes greatly to their professional development, as well as offering the students extra means by which to disseminate their research and practice to a wider cohort of people. Large universities, such as Warwick and Imperial, benefit from a huge variety of academic resources. We have therefore taken the request for writing training very seriously and have established a term-long scientific writing module at Warwick, where newly re-established relationships between the sciences and the humanities has allowed us to employ the expertise of staff in the English department, who also have science backgrounds, to provide training in journalistic and academic writing. This is not only beneficial for the students but also helps create a cooperative balance between and among disciplines with the potential to gain from each others' expertise.

Longer-term Outcomes
The course is a hands-on experience which allows students to see various sides of public access and media engagement. This fulfils not only a requirement of the students to relate their acquired knowledge to a wider society but also a national need to bring science back into the public interest. Waning scientific awareness is something that many academic departments would like to see reversed. If our students become aware of the need for knowledge exchange, and how to fulfil it, they become equipped to not only enhance their own skills but build very necessary bridges between academia, the laboratory and the outside world. Scientists need to re-establish communication links with non-scientists and young people in order for the discipline to continue growing and provide inspiration for the potential research workers of the future.

Students must be aware of the growing need for comprehensive achievement and to be prepared to take on the responsibility of becoming the highly skilled academics and researchers of the future in a highly demanding environment. It is not only the responsibility of the Higher Education Institution to train these students but also for they themselves to take control of their own learning. Courses like this help them to become aware of the value of the training they undertake and to be involved in the implementation and review process. The Doctoral Training Centres are dedicated to improving their training facilities in line with student demand as well as suggestions from Research Councils. Our practice is reviewed on an annual basis to ensure that the programmes designed for the students are meeting their shifting requirements. In addition the students are heavily involved in the evaluation processes and are invited to contribute to discussions regarding how best to improve their own training and personal development.

In addition the programme encourages partnerships, and exploits the resources and expertise available from various institutions. Networks such as these are essential for opening up further possibilities for enhancement.

Future Developments
We believe that other institutions and disciplines can gain valuable insight from our teaching experience and the ventures we have undertaken. In particular it seems self-evident that transferable skills are best integrated into the student's primary research activities. Moreover the need to disseminate information is not limited to the sciences, and the power and influence of the media need to be understood and exploited by all disciplines to provide maximum benefit. This programme can be adapted to impart the relevant skills and learning in almost any academic discipline or professional training. Offering intelligent students the means and the opportunity to learn something more about the avenues open to them can only broaden their horizons and enhance their outlook for the future. This is not specific to the media only, staff and students alike can benefit from the central achievement of improving communication and confidence in their skills.

This programme can be adapted to impart the relevant skills and learning in almost any academic discipline or professional training

The undertaking of this type of programme is of course not limited to the acquisition of time slots in a studio such as Bush House. Most university campuses are now home to their own recording studios or campus radio station; some may even have television facilities. But the underlying issue of the programme can just as easily be tackled with a video camera and audio recording equipment. On-campus facilities should give students a chance to complete live recordings with their newly acquired skills, which will enhance the satisfaction achieved from the undertaking. Such programmes inspire students to seek outside interest in their work and to develop a relationship between their personal interests and a wider community of people. Their own campus is an ideal place to start learning how to present their knowledge to a wider audience. It generates a greater awareness and a broader understanding of their horizons and thus of what they have to offer. Without these innovations we cannot expect to produce graduates of tomorrow ready to face a world in which the demand for expert knowledge and the exchange of up to the minute information is becoming a universal phenomenon.

We believe it will also be beneficial to share experiences with other centres conducting similar ventures, and also invite others to discussion regarding setting up their own courses in communication.

The success of this science communication module and of two others run by MOAC and CBC (namely Team Development for PhD year 2 and Decision-making and Leadership for PhD year 3) has encouraged us to develop a complete certificate in transferable skills which will be compulsory for Warwick DTC students in the first instance. The certificate will be taken over the three years of a student's PhD and is structured as 6 modules worth 10 CATs (or 5 ECTs) each. These are Key Skills 1, 2 and 3, each of which gathers together a range of skills we increasingly demand of our students (such as oral presentations, posters, financial management, writing for different audiences), as well as the focused residential suite of MOAC/CBC courses of the type described above, but with a more structured follow-up and assessment to ensure mastery of the skills. The postgraduate certificate will commence in October 2007 and we anticipate it will be a valuable vehicle for consolidating and enhancing the training discussed in this article.

Table 1: Programme for first Science Communication Course run by Gareth Mitchell at Imperial College and BBC Bush House January 2006.

CBC / MOAC Introduction to Science Communication Module **January 12 – 14, 06 Imperial College and BBC Radio, London** **Tutor:** Gareth Mitchell, Science Communication Group, Imperial College	
Thursday January 12 0945 Gather in room S204, 2nd floor, Imperial College Library 1000 Welcome and introduction to science communication Short exercise on where science news stories come from Introduction to science journalism 1115 Coffee break 1130 Introduction to *Question Time* television exercise Students already allocated to on-screen / technical roles Preparation and planning for afternoon's recording 1300 Lunch 1400 Gather in Imperial College Television studio Group A rehearse and record 1530 Group B rehearse and record 1700 Session Ends **Saturday January 14** 0945 Gather in room S204, 2nd floor, Imperial College Library 1000 Playback and review of radio programmes Conclusions and farewells 1300 Course ends	**Friday January 13** 0945 Gather in room S204, 2nd floor, Imperial College Library 1000 Review previous day's TV exercise and draw conclusions about television as a medium for communicating science controversy Introduction to science radio (with audio examples) 1115 Coffee break 1130 Discussion of evening's radio exercise Preliminary production meeting 1300 Lunch 1400 Preparations for evening's radio exercise continue 1530 Coffee served (work continues) 1545 Final production meeting 1715 Transfer to BBC Bush House 1800 Group A rehearse and record radio programme 1930 Group B rehearse and record radio programme 2100 Session Ends **Social dinner to follow**

Table 2: Selected student Science Communication Activities undertaken by participants after the January 2006 course.

2 students took part in a day introducing nanotechnology to the general public, predominantly to school children of GSCE and A-Level as well as some members of the general public. http://www2.warwick.ac.uk/newsandevents/pressreleases/NE1000000213210/
One student will take part in Showcase Science 2007 www.showcasescience.org and http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/E033474/1 running a stall on bio/nanotechnology
2 students were involved with 25 students from London International Youth Science forum (many winners of national competitions) visited to view equipment http://www.liysf.org.uk/images/pics/Brochure_2006.pdf
MOAC newsletter has been created by students
Talking to/entertaining friends and family etc (one student even made some of them sit through a Powerpoint presentation in a cafe)
One student's research has been mentioned on national radio: Five live, Anita Anand.
One student will give a biology lesson for sixth formers in a Solihull Grammar school in 2007
A number of students have talked with primary school age children and doing experiments with them
One student involved in 'Science Ambassador' which meant visiting 2 schools and talking about the importance of science
A number of students have visited secondary schools to talk about their science

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DUMP: A Database of Useful MCQs for Physics

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Our aims in this project were straightforward; to produce a browsable, online library of these materials that was freely available to all interested academics.

Abstract

This communication describes the output of a Development Project awarded in 2005 to fund a collaborative project between the Universities of Edinburgh and St. Andrews. The project aimed to take an in-house collection of over 400 multiple choice / multiple response questions on topics in introductory Physics (gathered and developed over many years of teaching) and publish them in an interactive, online, browsable collection, freely available to educators to use as a resource for their teaching. The system that we have created has functionality similar to online shopping or auction sites such as Amazon and eBay (without the cost!).

In this communication we will outline some of the rationale that led us to attempt this project, describe the issues and challenges for the project, illustrate ways the system can be used to support teaching and learning and conclude with thoughts for the future progress and sustainability of such systems, including plans for the continuing development of the output from this project.

Background

The role of technology in assessment - in delivering it, grading it and providing feedback on it, is becoming a very visible part of academic life for today's students. The current landscape and areas of rapid forward development have been reviewed recently[1,2]. This communication reports the output of a Development Project (2005-2006) that aimed to publish a collection of assessment materials (multiple choice / response questions) that we had developed over a period of years to support the teaching of an introductory course in classical Physics at Edinburgh. These materials had grown in a somewhat *ad hoc* manner over a period of time and had been mainly deployed to provide opportunities for students to obtain formative feedback on their conceptual understanding (…or otherwise) of the subject material. Effective formative feedback has the potential to transform the student learning experience[3].

In our case, the subject matter of the course aided us favourably in the art of writing questions. Drawing on an extensive literature related to the exposure of fundamental misconceptions in this subject material, we were able to author material that went beyond rote recall or manipulation, instead probing understanding of fundamental (or 'threshold') concepts which build the foundations for mastery of the subject[4,5]. Anecdotal (student questionnaires) and now more quantitative data[6] indicate these resources are both highly-valued and widely-used by students for on-demand formative assessment ('how am I doing?') during the course and additionally as a revision aid prior to end-of-course summative assessment. More recently, we have begun to repurpose some of these questions for use in interactive engagement episodes within lectures, using electronic voting systems[7].

At the same time as this Development Project, the HEA Physical Sciences Centre started a QuestionBank project, to design and populate a repository for a much wider range of question types beyond the simple MCQ/MRQ format used here.

Challenges

Our aims in this project were straightforward; to produce a browsable, online library of these materials that was freely available to all interested academics. But collections such as ours are certainly not unique; many others will have something like this and certainly all textbooks now come with supplementary material on disk or online (including some extremely sophisticated (subscription) services[8]. However, the demand within the learning object economy is for user-selected, shareable and interoperable resources. Many existing electronic resources fail to deliver these requirements. Staff need not necessarily re-invent wheels, but do need granularity and customisability ('I'd like this one but not that one'), together with an import / export facility ('We need it in this format not that one') to ease integration into local systems and / or methods of use.

The challenges, therefore, were to deliver this resource within a framework that facilitated easy browsing, discovery, reusability and interoperability of these materials.
The academic side of the project work was reasonably straightforward; to quality control the existing batch of questions, fill in gaps in coverage, and provide useful answer-specific feedback where it was lacking (essential if these materials were to be meaningfully used by students for formative feedback). However, it was in the technical development of the system that the majority of the effort was deployed. Here, we looked to the world of e-commerce for inspiration. The success of shopping and auction sites such as Amazon or eBay relies on an easy-to-use interface, allowing users to *discover* relevant things easily, from a huge range. The approach we adopted was to categorise resources into topics or categories to coarse filter resources, then add-in keyword filtering or text searching to discover appropriate resources. Figure 1 illustrates this, for a collection of resources on space and time.

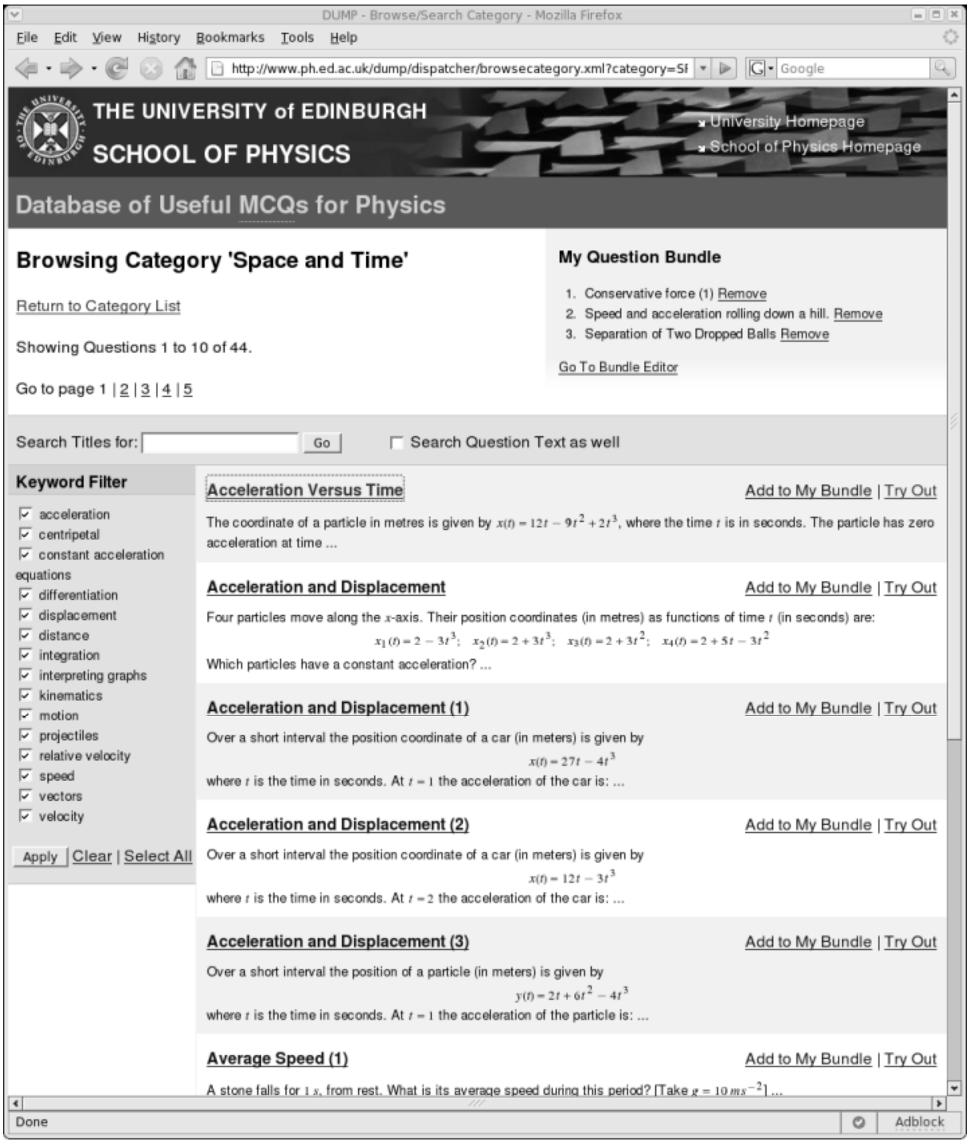

Figure 1: Discovery of resources within DUMP

The anatomy and functionality of DUMP
A detailed technical description of the inner workings of the system is not appropriate for this communication. It is, however, worth highlighting that the system reuses many of the components from our development of an in-house content management system for course resources[9], adhering to established and emerging web standards, such as utilisation of MathML for the display of mathematics online[10]. One of the design features is that a single ('golden') copy of the source is capable of being rendered in different outputs, (with appropriate question metadata used to categorise and classify each resource). This single-source, multiple-output approach is realised by storing resources internally within DUMP in XML format, and standard tools are used to transform this into various user-specified outputs formats. This directly addresses the issue of interoperability permitting export into widely utilised formats such as html (for online use), pdf (for paper deployment, perhaps as an in-class test) and emerging standard formats such as QTI[11] (for import into other delivery systems – such as virtual learning environments - or repositories).

It is always troublesome to animate a working system – to bring it to life and show its features and functionality - within the confines of a body of text and images. By far the best way to explore the system is in its native environment – online at http://www.ph.ed.ac.uk/dump. A simple registration process will allow you full access to all resources.

Figure 1 illustrates how groups of resources may be discovered via a combination of categorisation and keyword filtering or text searching. The matching results are shown, with the system displaying the question title, image as a thumbnail if there is one and the first 50 words or so of the question stub. The individual questions can then be viewed, either by clicking on the question title or the 'Try out' action link associated with each question. Figure 2 illustrates the per-question view after doing just that.

Having located and browsed individual resources, it is possible to export these from the library in various different formats. However, more commonly, people will want to build up a body of questions, perhaps relating to a particular topic. This is facilitated in DUMP using an analogy of the shopping cart in commercial sites, which we call the bundle. Questions may be added to bundles from either the per-question view (Figure 2) or the list of questions (Figure 1). The contents of the bundle are displayed on the top right of all pages and the bundle editor screen within the system (illustrated in Figure 3) allows for personalisation and export of bundled questions.

The sort of personalisation or customisation that a user might want to do before exporting a bundle includes aspects such as setting a title for the bundle, a bespoke numbering scheme, introductory text to preface the questions etc. There is then the choice of export formats. Currently supported formats are

- Complete interactive web bundle, that can be used as-is, mounted on a personal site, given to students on a pen drive etc.
- Various versions of a pdf format: a ‘student view’ with only questions; a ‘staff view’ with questions and correct answers highlighted; and a ‘full view’ of questions with feedback for each response.
- A QTI-compliant output channel.

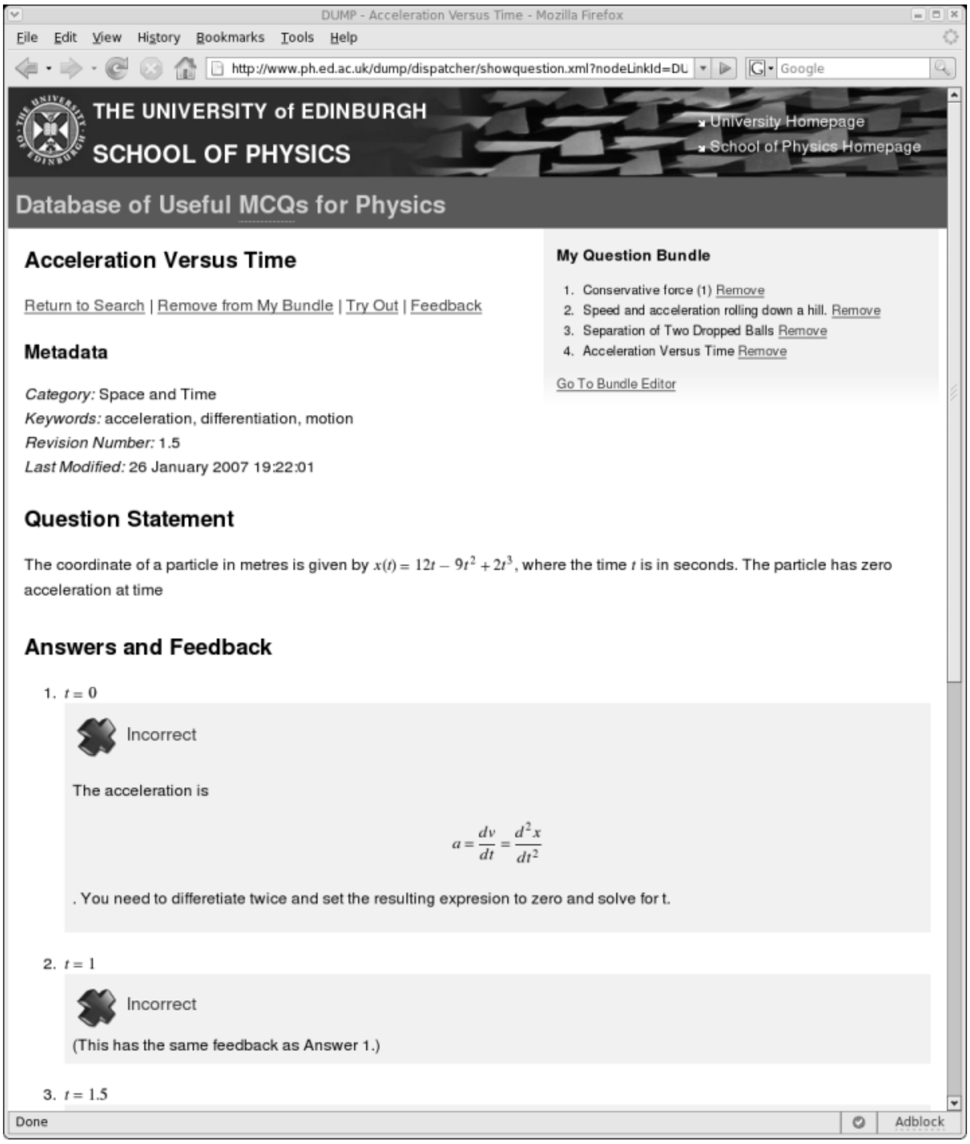

Figure 2: Per-question view of resources within DUMP

To date, DUMP has 38 registered users and contains over 450 questions, spanning predominantly introductory classical Physics, with brief excursions into optics and quantum mechanics. Having successfully designed and built the system, and populated it with a reasonable volume of useful content, we are developing the project further, not as ‘more of the same’, but as an opportunity to take something from cottage industry to more widespread adoption.

Previous experience has taught us that such developments require a critical mass of users and involvement to succeed; otherwise they are destined to become stale and stagnate. The current state of DUMP is that it does not yet have this critical mass, but we believe it is capable of achieving it. In the particular case of question banks or online repositories, probably the key issue is the bottleneck of content creation / provision. There are good examples of worthy systems or tools that lie sparsely populated, serving as a real disincentive to wider uptake amongst the academic community.
We have been fortunate to secure on-going Development Project funding through the Physical Sciences Centre to take forward this continued development. In particular, this follow-on project, DUMP2.0[12], will:

- Deliver a content creation interface for designated users;
- Provide for an export format for question bundles to Respondus[13] (or equivalent) for ease of importing directly into commonly-used VLE platforms;
- Evaluate the experiences of the existing group of early adopter users;
- Establish a successful and thriving community of practice around the DUMP system, exploiting the opportunities offered by the new wave of Web2.0 tools, facilitating online collaboration and communication.

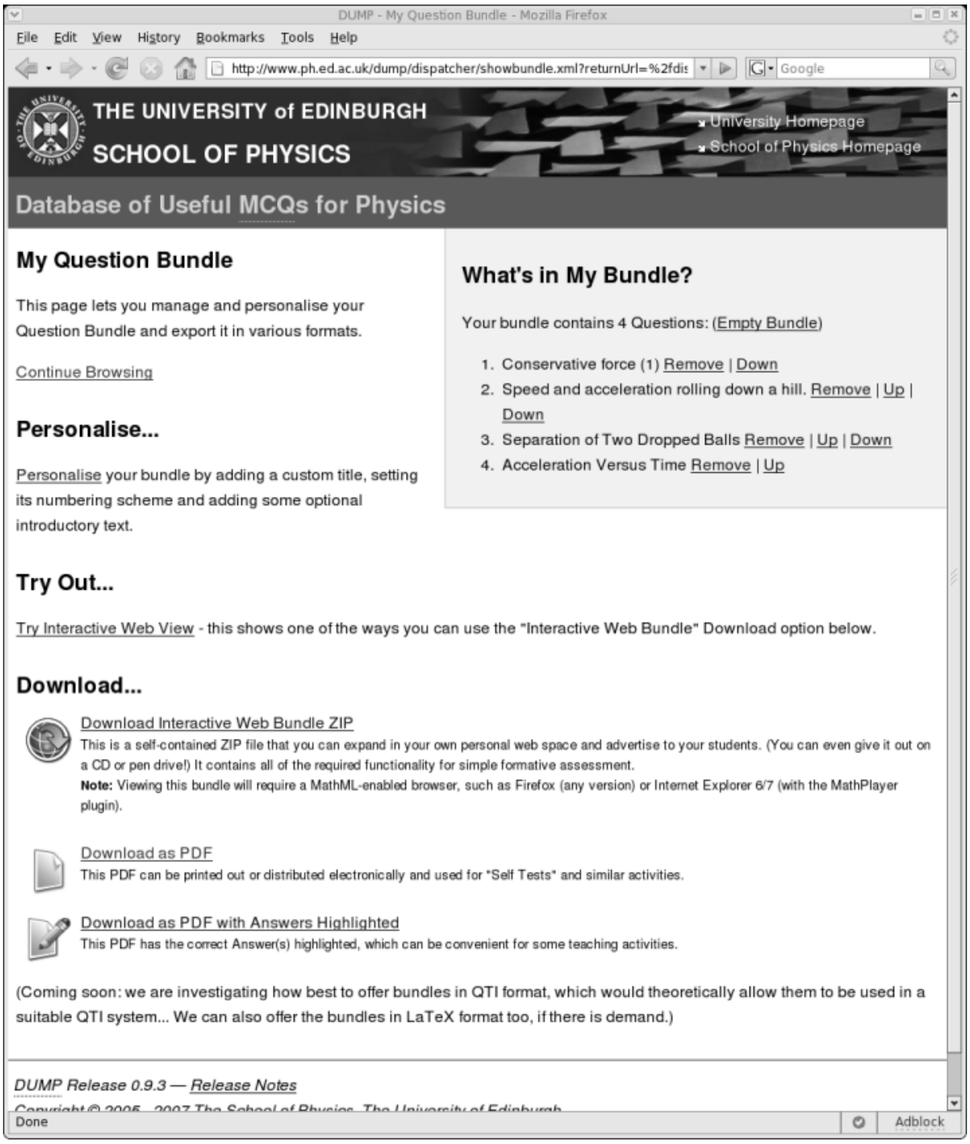

Figure 3: The bundle editor view of DUMP, with associated exports.

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The Use of Screen-Capture Video as a Learning Resource

Abstract

This paper discusses the use of informal screen-capture video clips as learning resources in mathematics and statistics for first year undergraduate science students who possess a minimum grade C in GCSE mathematics. The videos are quick and easy to produce and provide a valuable extension of the personal tutor-student interaction. Hand-written text, as well as data analysis in suitable software, can be recorded to provide a permanent record of the solutions to many different types of problems.

The underlying approach of learning provision for skill-based modules in the first year is to meet a diversity of intake with a diversity of learning provision, and this paper highlights the variety of roles that this particular form of video material can play.

Introduction

First year science students often struggle with mathematics. This article reports developments within two modules that provide the main mathematics and statistics input for first year science students at the University of the West of England. In 2006/2007 the 20 credit module, Scientific Inquiry had 185 students, and the 10 credit module, Scientific Data Analysis had 142 students.

There is a very diverse intake to these modules, from mature students who last struggled with mathematics many years previously, to school leavers with reasonable A-Level passes in mathematics. The median student typically completed formal mathematics at GCSE level some two or three years earlier.

The essential problem, within a resource-limited environment, is to provide appropriate learning resources for the weak 'tail' of the student distribution, whilst at the same time giving the capable students a coherent and satisfying experience.

The essential problem, within a resource-limited environment, is to provide appropriate learning resources for the weak 'tail' of the student distribution, whilst at the same time giving the capable students a coherent and satisfying experience.

With feedback from previous years, it became clear that the two main problem areas were:

- A common lecture, being used to present an overview of new material, was failing to reach the weak students and was still boring for the capable students.
- Students were reluctant to access the worked answers (in pdf files) that were available on the website for the course textbook[1].

From the students' points of view, the input of new material was not well designed, and the feedback for worked problems was not user-friendly.

The author had recently started investigating the use of the screen-capture software Camtasia[2], with the intention of developing educational videos. However, a decision had to be made: whether to produce

- substantial videos to present new material in support of the lectures, or
- many short informal video clips to present user-friendly answers to student questions?

It was felt that the video clip answers would provide the solution to a problem that could not be solved easily in any other way. The weak students could re-run videos of difficult problems as often as they wished in order to understand the answers. The capable students may only need to check that they have the correct result, or possible skim through the video to check the method.

The remaining problem of presenting the new material was addressed by abandoning the common lecture for tailored lecture/tutorial sessions for smaller groups, selected on the basis of an initial diagnostic test.

On balance, the new developments have been time-neutral for staff, in that extra time is spent delivering the new material in a more 'tutorial' environment, but less time is spent in providing repeated answers to a succession of individual enquiries. Overall, this also gives a more satisfactory interaction with the students.

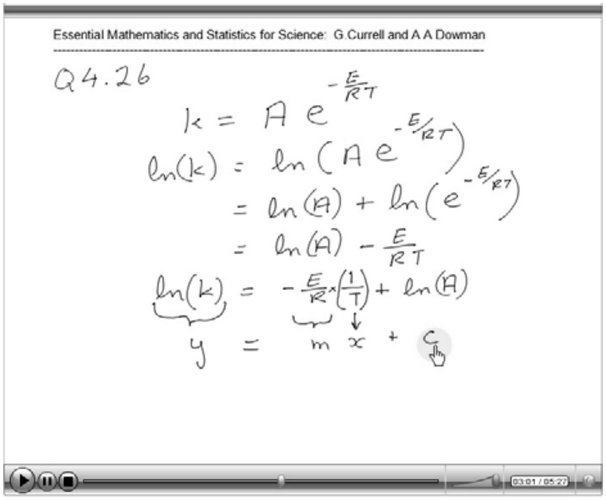

Figure 1: Video frame: Answer to a linearisation question

The videos were designed to replicate the situation whereby a student might ask the lecturer for the answer to a problem. The lecturer would give a verbal explanation, together with a hand-written answer, and the student would typically ask to keep the 'hard-copy' version. These videos record a hand-written answer using a tablet PC, together with an audio commentary. With the video, both the audio and the 'hard-copy' versions are permanently available for the student to review the answer.

The videos last for only a few minutes and can be accessed directly as flash videos via a hyperlink on a web page. A cursor bar in the video 'screen' enables the students to drag the recording to any point on the video for repeated viewing.

Some examples of the prototype videos can be viewed at: http://science.uwe.ac.uk/mathsstats/videolink/video.htm

Video Production

The software, Camtasia, can be used to record any activity displayed on the computer screen, and, together with the recorded audio track, is able to produce video files in a number of standard video formats. It can be used, for example, to make specific recordings from PowerPoint[3] or to produce step-by-step recordings to demonstrate the use of any software such as Excel[3].

The editing functions in Camtasia allow recording of an additional audio track, the inclusion of some useful effects (callouts, zoom and pan), as well as (for flash format) interactive quizzes and hyperlinks to other resources.

In the production of the 'feedback' videos, the 'hand-written' text was produced by using a tablet PC to record the writing with a screen pen on an open Word[3] document. It was also possible to add any printed material, text, graphs, etc, by importing it into the Word document from other software.

An important issue was whether to prepare a written script, or just to speak 'off the cuff' when working through the problem. A fully drafted script can sound quite flat unless recorded by someone with excellent presentational skills, and, additionally, can often appear to lose its close link with the working on the screen. On the other hand, a 'speak as you write' approach comes across as a more personal and realistic delivery, but can be very frustrating to record as frequent hesitations, ambiguities, and errors creep into the recording, and need to be edited out or re-recorded.

Experience now suggests that the balanced answer to scripting involves:

- good preparation in anticipating each step that will be followed in demonstrating a solution,
- detailed scripting of particular phrases that are key to the mathematical reasoning and cannot be allowed to become ambiguous, and then
- a relaxed and impromptu commentary for the rest of the answer.

Finally it is necessary to choose an appropriate video format from the main options: Windows Media, QuickTime, AVI, Adobe Flash. The types of videos recorded in this project have only a limited amount of changing information between each 'frame', compared with full screen motion video.

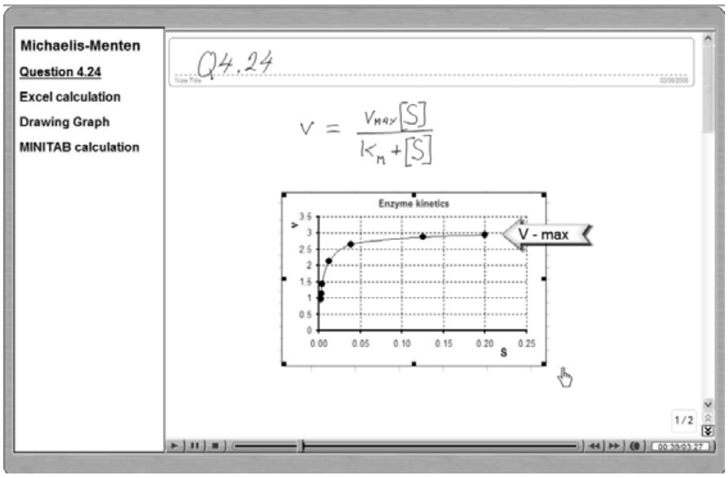

Figure 2: Video frame: Camtasia 'theatre' incorporating several linked video clips

Consequently they can be conveniently delivered as 'swf' flash videos viewed directly from the internet using relatively small file sizes – typically less than 1Mb for a 2 minute video. However, with the flash format it is not convenient to provide a download facility for later viewing, but this has not proved to be a major disadvantage as far as most students are concerned.

During 2006/2007 video clip answers were produced for:

- 185 questions in the course textbook,
- 80 questions in 8 self-assessment tests,
- 40 questions in an initial diagnostic test,
- 48 questions in two specimen examination papers.

In addition, videos were developed to illustrate the use of various software techniques based on Excel and MINITAB[4].

Student Feedback

The students were very enthusiastic about the videos, and the overall pass rate for the modules increased significantly. The videos had a particular value for the weaker students, who recognised the importance of being able to pause and rewind them to concentrate on understanding key steps in the answer.

In feedback from 26 students, their mean ratings for the values of various learning resources were recorded on a scale of 1 to 4:

Video answers to questions from the textbook.	3.58
Video answers to self assessment test questions	3.16
Video answers to specimen examination questions	3.55
Course text book	3.04
Lectures/tutorials	2.80
Computer workshops	2.24

Values (rated 1 – 4) of various learning resources

The high value placed on the videos was gratifying, although it should be noted that these were responses to a questionnaire posted via email and the internet and may represent a more ‘IT sympathetic’ sample of students.

The relatively lower response for the value of the lecture/ tutorial resource shows that it is still necessary to improve the initial delivery of material. In addition, there are already plans in place to improve the computer workshops, whose purpose is to develop data analysis and data presentation skills.

When asked to suggest possible improvements to the videos, there were very few suggestions other than to increase the range of skills covered by video instruction, particularly in the context of teaching skills in using Excel and MINITAB. This is consistent with the known difficulties that some (often mature) students have in the computer workshops with these skills.

Beyond concluding that these videos have been very useful, it has been difficult, within an evaluation questionnaire, to establish which characteristics of the video are actually relevant to the effective learning of the student. For example, some staff commented that the videos were too slow, but, when specifically asked, no student agreed with this view, and indeed there was a suggestion that some videos should take more time over detailed calculations. Similarly, many professionals compare the videos to the expensive, polished, productions available on DVD, but in fact it may be the very informality of simple presentations that provide a comfortable environment for the student to learn.

Future Developments

The main directions for future development involving the video technology include:

- improving the integration between the course textbook and the video answers,
- developing more interactive self-assessment testing using direct links to videos within the tests themselves,
- using video technology to share skills amongst staff as well as students,
- researching the characteristics that make an educationally ‘good’ video, and
- developing both the technology and the pedagogy into other disciplines.

The interaction between book and video is being addressed by writing a second edition with an upgraded website to provide integrated feedback available for all the questions in the book.

Hot Potatoes[5] software is also being used to develop learning packages accessible via the internet. These packages will be based around self-assessment questions which themselves interact with video overviews and feedback. The compatibility of these packages with major VLE (virtual learning environment) systems is being investigated.

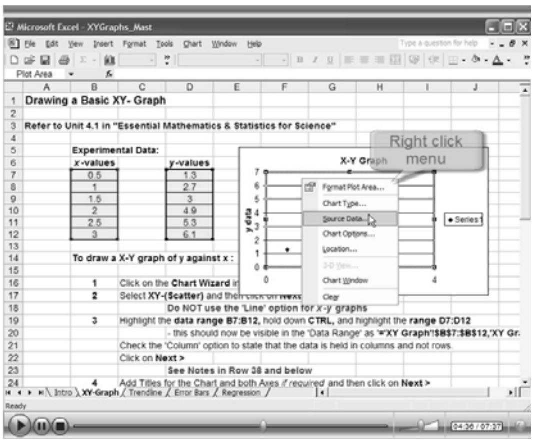

Figure 3: Video frame: Step-by-step instructions for editing an x-y graph in Excel

It is intended to develop a website to host short video clips that demonstrate specific software skills that are relevant to both students and UWE staff. Examples could include the use of various software packages for aspects of scientific data analysis and presentation, the preparation of flash videos, and the development of web-based learning and self-assessment packages.

In 2007/2008, it is anticipated that four final year project students will begin to investigate which content and production characteristics have the greatest influence over the effectiveness of different types of learning support videos.

Finally the University of the West of England is also contributing to the CFOF (Chemistry for Our Future) project (funded by the Royal Society of Chemistry) by developing interactive videos which will support students starting chemistry courses in their first year undergraduate studies.

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The students were very enthusiastic about the videos, and the overall pass rate for the modules increased significantly. The videos had a particular value for the weaker students ...

Why Bother Taking University Led Chemistry Outreach into Primary Schools? Bristol ChemLabS Experience

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Abstract
The School of Chemistry, University of Bristol is taking postgraduate Chemists and circuses of practical chemistry experiments into primary schools to enthuse, excite and educate tomorrows chemical scientists. With over twenty workshop visits undertaken in 15 months we share our recent experiences.

In 2005 the School of Chemistry at the University of Bristol became a HEFCE Centre for Excellence in Teaching and Learning (CETL), the only one dedicated purely to Chemistry. The CETL project, known as Bristol ChemLabS (Bristol Chemistry Laboratory Sciences), is focused on the development of practical work for undergraduates. A second strand of the project is to expand its Outreach activities with a number of groups. Apart from the usual targets for such activities, i.e. those in the wider community and secondary school students, Bristol ChemLabS also decided to explore Chemistry Outreach events with UK primary aged pupils (4-11 years of age).

Local regulations do not allow primary aged pupils to use the laboratories at Bristol University's School of Chemistry. To engage with this cohort therefore requires the School of Chemistry to move out of the university and into the primary schools themselves.

Three modes of engagement have been tried. The first mode was an on-line science quiz that was trialled with 1200 local pupils registering in 2006. The quiz, using questions from the Key Stage 2 (KS2) Science curriculum, was hosted by the university's existing computer resources. Pupils were presented with certificates at gold, silver and bronze level according to their scores. This approach is running again in 2007. Second, Chem@rt is a gallery of around a dozen images taken from recent chemical research at Bristol and is sent out to schools to act as stimuli for written work (poems and prose) by pupils of all primary ages. The class teachers nominate winners per class per image and all students who take part receive certificates with the winners receiving gold awards. Between 5000 and 6000 pupils took part in the southwest of England in Chem@rt006. The follow on, Chem@rt007, has already been launched. The main thrust of our work, and the subject of this article, is the taking of practical chemistry exercises into schools.

Taking practical chemistry into primary schools is also the most time demanding and resource intensive engagement activity. A typical day in a primary school consists of a full school assembly and two workshops each comprising a circus of experiments.

Taking practical chemistry into primary schools is also the most time demanding and resource intensive engagement activity. A typical day in a primary school consists of a full school assembly and two workshops each comprising a circus of experiments.

The assembly is generally given to the entire primary school population which can be an audience ranging from 100 to 400 pupils aged between 4 and 11 years of age. The demonstration assembly is normally about the gases in the air which acts as a good excuse to use liquid nitrogen, dry ice, perform the elephant's toothpaste experiment, to set fire to a few materials including hydrogen balloons and compare them to the helium filled versions. Care is taken to relate the experiments demonstrated to the science curriculum and, more importantly, the terminology used at KS2.

The practical workshops last a little over 2 hours each so that two classes per day can experience them. The pupils are usually in Year 5 and 6 although in some small rural schools this can be a mixed group of pupils from Years 4 to 6. A normal primary classroom or a school hall is temporarily turned into a lab for the day. Three large groups of tables each house an experiment. All pupils, and accompanying teachers and teaching assistants, are fitted out with appropriately sized lab coats safety glasses and gloves. Each experiment is supervised/demonstrated by either a postgraduate Chemist or the School Teacher Fellow.

The primary school usually lets Bristol ChemLabS choose which experiments to be used. The small suite of experiments available is designed to reinforce measurement, investigatory and cooperation skills. Typical experiments involve the pupils working in pairs and correctly using measuring cylinders and stopwatches. No time, other than that needed for recording measurements is spent in writing and little time is spent in reading of worksheets. Instead instructions are given orally by the postgraduates working with the groups of 12 pupils. Also it is felt that time spent in discussion of results and observations with young practising chemists are more worthwhile than written observations. Any follow-up written work can be undertaken by the class teacher in a later session.

Figure 1: Pupils reinforce measuring, observational and team work skills during the circus of experiments

What is the circus of experiments that make up a workshop visit to primary schools? Examples of experiments include adaptations of the iodine clock experiment, work on polymers, the rate of reaction between dilute acid and magnesium, thermochromic pigments and the chemistry of toothpaste. In the iodine clock experiment the pupils are shown the reaction and are asked to investigate the volume of water needed to make the clock change colour at a target time such as 60 seconds. Discussion of safety, fair testing, accuracy in measurement, team work and reproducible results are thrown up by this experiment as well as the acid magnesium investigation. The pupils like the element of competition and some simple prizes are given to the pairs that are the closest to the target when the 'judge' does the timing! In the polymers workshop pupils investigate the degree of cross linking of PVA with borax in making slime, the source of PVA white glue versus the 'pure' PVA source and the thermoplastic properties of the polymer available as 'polymorph'. The polymorph experiment also lends itself to a brief model making competition. The toothpaste workshop starts with a mind mapping exercise on what makes good toothpaste. Several small experiments that compare pH, frothiness and stickiness of several commercial toothpastes are then undertaken.

In the thermochromic workshop a discussion of paint properties is followed by the making of thermochromic paint by mixing appropriate pigments with acrylic paint in very small quantities The temperature at which the paints change colour is then investigated by painting plastic cups and adding hot and cold water until the temperature of the colour transition is discovered. For specific examples of outreach visits in primary schools please see Bristol ChemLabS outreach web site: www.chemlabs.bris.ac.uk/outreach

All the postgraduate Chemists that are involved with these engagement activities have been trained through the Science and Engineering Ambassador Scheme (SEAS). The training involves discussion of the responsibilities of the postgraduates and of the class teacher during outreach visits, what to do if… scenarios, a session on the absolute need to be able to communicate at an appropriate level with the target audience and appropriate professionalism whilst in schools, e.g. punctuality. Lastly the PGs will also have a Criminal Records Bureau (CRB) check completed, a necessary requisite to work with school age pupils in schools. The SEAS are also insured as part of the scheme. Over 100 postgraduate chemists at Bristol have been through this training in the last 18 months. The benefits to these postgraduates of such endeavours are the subject of a future publication, but these will include the

Figure2: A young chemist displays her freshly made PVA slime

training they receive in public engagement and further communication skills they acquire. All postgraduates involved have reported that the interaction was a positive one and several have reported very positive outcomes.

Where does the finance come from to support the visits? Outreach to primary schools need not be a charitable act. To take 2 or 3 experienced postgraduate chemists into a school with £4k worth of equipment does cost a fair sum of money. Travelling expenses, accommodation, technician time, disposable costs and laundry are just some of the costs involved that need to be met. Bristol ChemLabS does ask schools to contribute to these costs. Schools have access to a variety of funding sources, from Gifted and Talented funding and special projects funds such as those put aside for science weeks. Other funding sources include the local branches of the Royal Society of Chemistry (RSC). Local specialist science colleges have also funded workshops for their family of primary schools. In our experience the availability of funds to support good quality science outreach activities for primary schools does not appear to be a problem.

How do we know whether this sort of activity will lead to an increase in Chemistry uptake at A-Level or degree and does that matter? Tracking pupils from 10 to 19 years of age would be expensive and time consuming. Naturally formal and informal feedback from primary headteachers, primary

Figure 3: School teacher Fellow Tim Harrison demonstrates liquid nitrogen as part of the whole school assembly talk on 'gases in the air'

science coordinators (most of whom are not science specialists let alone chemists), class teachers, pupils, and the postgraduate chemists themselves is sought, reviewed and acted upon. We have also had experience of feedback from parents of pupils that have experienced chemistry workshops. Gut instinct and ephemeral evidence is that such activity must be a contributing factor to selection of A-Levels. When asked what prompted her into studying chemistry one Bristol

Figure 4: The pleasure of doing practical chemistry in a primary school is evident!

postgraduate Chemist related a story about a visit by a scientist to her own primary school. Even if not, such activity is worthwhile in its own right even if it simply supports colleagues in science education in the primaries.

One primary teacher recently reported that when a parent at Parents' evening asked whether her son was still intending to be a professional footballer the boy replied "No. I am going to be a research scientist". Whether we have lost a future David Beckham or gained a Chemistry Nobel Laureate would be impossible to tell.

Summary
Primary school outreach need not be financially draining to a chemistry department, schools can pay for activities and there are other sources of funding available. Primary science has virtually no Chemistry input at all, dominated by Physics and Biology (Botany) with some meteorology. Primary school pupils relish the opportunity to carry out real Chemistry investigations and all feedback has been extremely positive. Primary science teachers are often non scientists and find the workshops we run as exciting and engaging as the pupils and welcome the contact with practising scientist. It is too early to tell whether the Bristol ChemLabS primary outreach program will have a long term impact on the pupils it has engaged, however the immediate benefits in terms of feedback suggest it will. The SEAS training scheme provides an excellent platform for postgraduates to take part in this activity and they too reap significant benefits in terms of personal development by taking part in this activity, as well as being excellent role models to these young people.

In our experience the availability of funds to support good quality science outreach activities for primary schools does not appear to be a problem.

Appendix
Quotes from thank you letters written by pupils at Moss Hall Junior School, Finchley, London

I had a great time when you came and it was extremely fascinating. Since then I have learnt a lot and now want to study further, not just because of the experiments which were fantastic –but Chemistry is an exceedingly interesting subject. (Excerpt from newsletter to primary parents)

I have never done anything like that and I really enjoyed doing it. I also learnt a lot of knew words…. It was the best science lesson I ever had! Rhianna

The workshop was one of the most interesting events ever at our school. So was the assembly. Now I am really looking forward to doing chemistry at secondary school. I am even going to do it at GCSE when I am older! I am really interested now in scientific things. Toby

I hope you come back and visit us again with more interesting experiments.
Charlotte

My dad says when I am older I will go to Bristol University.
Finbar

I can't wait to learn about chemistry at secondary school.
Madeleine

I liked the bit when you froze the banana…..I never knew science could be that fun. Ruby

I really liked the workshop tasks because we got to wear the safety goggles, the lab coats and rubber gloves. It made me feel like a true scientist. James

It was fascinating to learn about gases and chemicals. I told my family all about it. Julia

I had a great time and I might learn chemistry when I am older. I would like go to your university and learn more chemistry with you. Nadav

Thank you for your assembly. It was the most exciting assembly I have ever had… I thought it might be good if I (were to) be a scientist. It was my first time using (a) chemical. Tatsuma

My favourite bit was blowing up the balloons… when there was a sheet of flame. I thought it was the best school day of my life. Taishi

You have really encouraged me to become a scientist like you. Thank you very much. Daici

It was very fascinating to learn the stuff you do especially that we're in junior school and most people only get to do it in secondary school. Julia

Assistive Learning and Research Mentoring Schemes

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Abstract
The adoption of undergraduates into research teams upon entering university represents a marked change from the prescriptive lecture-lab format that underpins current teaching formats within the physical sciences. One such approach has been piloted at Nottingham Trent University - though not as a replacement for traditional teaching methods but rather to compliment and enhance the university experience for new entrant undergraduates. The programme has aimed to foster a student centred approach to their studies within chemistry through providing a genuine, real world context wherein they can tackle real problems that will help to reinforce the academic content and develop transferable skills. While the programme can be viewed as an enhanced work experience programme for undergraduates, its principal aim is to provide a pro-active mentoring framework that will nurture student enthusiasm for the subject. The logistics of running such a programme are outlined and the preliminary outcomes from the initial pilot are discussed.

Introduction
At present, most undergraduate research within university curricula is largely restricted to final year projects. There are good reasons for doing so, under the assumption that students will have gained, in the previous two years, the core knowledge that should enable them to function relatively independently within the laboratory environment. The project is widely perceived by students as being the most interesting part of the course – largely as a result of the independence, the challenge of the new and the fact that the results obtained could have real world significance. Could the same not be applied to first and second year students? Assistive Learning and Research Mentoring is a Development Project funded by the Higher Education Academy that has sought to assess the potential impact of attempting to introduce entry level students to research as a means of enhancing their undergraduate experience.

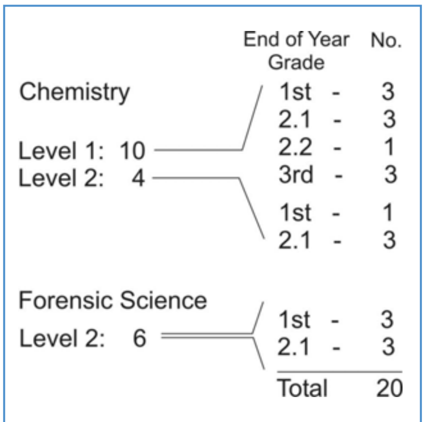

Figure 1: Academic ranking at the end of the first year for students in pilot study

The basic rationale was to provide an integrated mentor scheme that offers a framework to complement the traditional Lecture-Lab-Tutorial teaching protocols that are common to most science degree programmes

The basic rationale was to provide an integrated mentor scheme that offers a framework to complement the traditional Lecture-Lab-Tutorial teaching protocols that are common to most science degree programmes. It was hoped that the scheme would provide students with a mechanism through which they could, to a limited extent, direct their own studies within an easily identifiable real world context. The approach taken here has been to adopt undergraduates into active research groups and encourage their direct participation in a range of multi-disciplinary projects. This offers an opportunity to provide excitement in a way that is immediate, upon entry to the course, tangible, through the development of key skills, teamworking and real world problem solving, and desirable, by providing individual identities and visible career enhancement. The distinction between school and university is clarified and, with the opportunity to participate in something real, a sense of importance can be fostered that should enhance the esteem of the individual student. Buddy schemes have been used extensively as a means of bridging the school/university transition for new entrants, but these often provide little more than an opportunity for social familiarisation with the campus setting. It was anticipated that the research mentoring programme, in contrast to undergraduate pairing, would provide a more structured support network that could serve to counter or alleviate the more academic concerns of those new to the university.

There are obvious problems in the implementation of such programmes: the limited scientific background of the student, the availability of instrumentation, health and safety considerations, the possible expense and the increased time demands placed on the supervisor. When would it be done and would it require additional timetabling? How would it impact upon the student workload? These are the main questions that the project has sought to address. The project has an initial lifetime of three years, such that the progress of students from Year 1 through to graduation could be followed. At present, it has been running for almost two of the three years originally specified and a preliminary evaluation of the scheme and its participants is now presented.

Project Methodology
The basic plan was to allow students an opportunity to engage in a number of distinct research projects. Recruitment to the scheme was purely voluntary, was not assessed and no additional timetabling was required. Irrespective of course programme, there will inevitably be periods where the students have blocks of free time. In our experience this is usually the Wednesday afternoon traditionally reserved for those with an interest in sports. Students were assigned a project and, after an initial induction period, were given a particular part of the project on which to work, through which they would engage in the process of research. Supervision was based on the close interaction between student and postdoctoral or postgraduate supervisor, who would then report to the academic supervisor. The overall aim is to foster an effective working partnership in which the student actively contributes to the group.

The scheme essentially mirrors a work experience programme but one where the outcome and direction can be dictated by the student, albeit with a modicum of surreptitious academic guidance.

The scheme essentially mirrors a work experience programme but one where the outcome and direction can be dictated by the student, albeit with a modicum of surreptitious academic guidance. The students are provided with an arena that can enable them to place their studies in context and to hone their skills on something more tangible than that offered by library study and recipe based practical sessions. The programme is run as a complementary activity to the existing laboratory work and is not intended to replace the latter. The key advantage is that as there is no formal assessment, the pressure of failing is removed and the burden of 'mistakes' is shared by the supervising researchers in an environment that actively promotes a supportive teamworking and problem solving ethos that enhances the development of key skills. It would be hoped that the improved confidence generated by the additional laboratory work would provide a positive feedback into the programmed laboratory sessions.

Project Implementation
A total of 20 students have engaged in the pilot project since its inception in October 2005. These were drawn predominantly from the Chemistry cohort with six students recruited from the Forensic Science programme. This accounts for approximately 8% of the new entrants within the chemistry stream. The breakdown of the respective groups and their academic ranking at the end of the first year is detailed in Figure 1. It is clearly not possible to let the students simply run free within the laboratory environment. Adoption within a research group however could essentially overcome many of the negatives highlighted previously. A key tenet is that the research and support staff are willing to supervise the students during their time within the laboratory and hence maintain compliance with appropriate health and safety practices. The academic should thereby be released from the demands of having continually to watch over the students while the students gain the freedom to experiment and develop their skills without the consequences of formal assessment.

An assumption is that the supervisory duties can be distributed amiably amongst the research staff (postgraduate and postdoctoral). In principle, it could be an effective means of providing those players with an opportunity to develop their own mentoring skills. In so doing, it could be a highly effective vehicle for promoting 'Life Long Learning' staff development goals. In practice, this will obviously be dependent on the individual concerned and their own workload. In the majority of cases, the opportunity to supervise students has been met with a high degree of enthusiasm. It has to be acknowledged that in the initial phase there is a large investment in time on the part of the supervisory team to bring the students up to speed with the running of the particular laboratories, establishing competency in the various tasks and on the specific demands of the project itself. In the long run however, this can be largely offset as the new entrants become the supervisors in the second year. In principle there is the potential for a self perpetuating cycle that actively reinforces the student confidence for new entrants and established members.

The ability and desire of students to participate within a research environment is woefully undervalued. The enthusiasm and inevitable 'but why?' questioning can, with a little imagination and appreciation of the students' educational level, be harnessed to benefit most research processes irrespective of division. This is not to say that they can be immediately engaged in cutting edge science, but there is always a role for smaller, proof of concept, projects. The interaction of the various groups also brings the benefits of developing much heralded transferable skills (teamworking, problem solving, communication, computing) and can also foster a competitive edge that helps to drive the students and the project forwards. Many courses place great emphasis on their 'Scientific Communication' modules and this scheme can clearly form synergistic relationships across a range of modules with the research project providing a strong contextual basis.

The ability and desire of students to participate within a research environment is woefully undervalued

Project Evaluation
The project is being evaluated on a number of levels and includes: determining the type of student that opts for the programme; the weekly attendance of the students and the impact of coursework on this, the attrition rate over the year; continuation into subsequent years; the possible influence that the additional training has on placement interviews and the impact on their academic performance (laboratory and final exam). The low sample number will create an obvious problem when attempting to ascribe statistical significance to any trends that emerge from those participating in the programme in comparison with the bulk of the chemistry cohort. To counter this, at least in part, the programme is being evaluated over an initial three year period which should give a more detailed assessment of how the students have progressed over the entire programme. It can be seen from Figure 1 that it appears to cater for the more gifted student despite the fact that it was open to all and there was no discrimination in the recruitment process. It is clear however that the programme self-selects and a sad outcome is the fact that it is largely ignored by those who could benefit the most in terms of the need to improve academic performance and laboratory skills. This induces an obvious problem in attempting to elucidate the influence on academic performance beyond the anecdotal as it could be argued that the students would have achieved similar results even if they not taken part in the programme.

Preliminary Conclusions
A number of reasons can be attributed to the bias in the recruitment statistics: the principal factor may however be the perception of the increased workload. It could be anticipated that the more able students feel confident in juggling the additional commitment. Part time employment must also be considered and will impact on student participation. The fact that the programme runs within the existing curricula can, in part, offset that potential conflict with part time employment. Nevertheless, it is an important factor that imposes increasing time constraints on students and it must be acknowledged that the majority of those taking part were not subject to the demands of evening or weekend employment. The programme clearly provides a worthwhile contribution to the student experience, as evidenced by the relatively small attrition rate over the first year. The project has also realised tangible and indeed notable results. A number of research publications[1,2] have arisen in the course of the first year work and students have won a number of prizes at conferences at national and regional level for both poster[3] and oral[4] contributions. In response to the preliminary evaluation, the second phase of the programme has been to actively encourage the participation of weaker students, especially those entering their second year. This group may provide a stronger foundation for assessment of the potential impact on academic performance as their initial, first year, results will provide a more reliable benchmark. The fact that the first year of the programme has given rise to recognisable outcomes that can significantly enhance the student CV can be used to advertise the merits of participation in contrast to a view of the programme as simply yet more coursework.

Acknowledgements
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The programme clearly provides a worthwhile contribution to the student experience, as evidenced by the relatively small attrition rate over the first year.

First years enjoying physics? (The Undergraduate Physics Olympics)

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A potential solution already existed in the form of the very successful Physics Olympics, developed ... as an outreach event ... and since syndicated around the world

Abstract

The Undergraduate Physics Olympics (UPO) was run for the first time in the second semester of the 2005/06 academic year. The aim of the event was to enhance the first year experience by organising teams of freshers to compete for prizes on a set of practical physics challenges. Over the course of an afternoon each team of 4 had to race against the clock to design and build a boat, set up and use their own code, and demonstrate linear acceleration in the park outside. Communication between students was encouraged by awarding points for bonus questions demonstrating good team spirit as they prepared for their first laboratory sessions together. The event also enabled students to be introduced to the departmental laboratories, and to the staff and more senior students in an informal environment, at an early stage in the year.

A full evaluation of the first event was carried out by a final year project student in order to perfect the format for use during a more appropriate time slot during Freshers' Week. The second event in September 2006/07 was also well received, with many of the previous year's participants volunteering to help run the event. Statistical and anecdotal evidence both indicate the UPO is an enhancement of the first year experience, helping to build peer support groups, vital as the first year intake steadily increases.

Background

In the 2005/06 academic year, lecturers and tutors observed that this particular cohort was very focused on results, to the extent that they allowed themselves little time for communication of ideas and reading around the subject. This was compounded by the current design of the first year programme, with little opportunity for teamwork and no laboratory work until the second semester.

I applied for funding from the HEFCE Teaching Quality Enhancement Funding (TQEF) to implement some simple, but immediate intervention. The start of the second semester allowed for available timeslots at a time when students are under less pressure from coursework deadlines and exams, and offered maximum impact potential.

The aim was to design an event which would provide opportunities for first year students to:

- improve communication between students.
- work in a team from early on in the course.
- interact with more senior students and staff members in an informal environment.
- get some practical physics experience early on in the course.
- perform some simple 'fun' experiments.

The Solution

A potential solution already existed in the form of the very successful Physics Olympics, developed in the 1990s by Dr Dominic Dickson as an outreach event in the University of Liverpool and since syndicated around the world. The format of this event is a competition involving teams of 4 completing physics 'challenges' to a time limit with a quiz running in parallel. As this had been tried and tested on A-Level students there was equipment for many possible challenges available at an appropriate level. In addition several senior undergraduates agreed to share their experience of demonstrating and judging this event.

The Undergraduate Physics Olympics

The adaptation of this format for our first year undergraduates was a simple matter, though the time limitation may be obvious from the unoriginal choice of title. During the 3 hour afternoon slot, the students were divided into teams according to whom they associated with in lectures, in order to give them the opportunity to work with new peers.

They were then expected to complete each of the 4 challenges, the quiz, and some bonus questions before team photos and a prize giving ceremony. The event was hosted in a large laboratory with music of the students' choice played at background level.

The challenges involved simple materials and had to be completed, including judging, within 25 minutes. The students were provided with 1 sheet of A4 paper for information, setting out the task, listing the set of materials, and the judging criteria in the clearest format possible.

Bonus Round
As a bonus round I approached teams randomly, after they had had some time together, and asked them each to name another member of the team. Less than 50% of teams could all name another team member, but asking inspired some good spirits and friendly interaction as teams watched their friends in other teams at a loss.

Prize Giving
The competitive element stimulated a lot of interest and a short prize-giving was held after the final session. This was a very light-hearted affair with a slideshow of photos of the whole event running in the background. A brief summary of successes and anomalies was given, and the winning team of each event was called forward to draw random prizes (£4-6) from a large box. In the prizes we aimed for variety with only 2 or 3 of each type, so interest was high throughout as each student figured out what their prize was or did. The overall winners, who incidentally had not won any single event, got prizes worth ~£10 each. Finally all involved drew a random memento (£1-2) from another box to reinforce the positive attitudes towards their learning experience.

Figure 1: What frame of boat will support the most marbles?

The Challenges
The most popular challenges:
Make a craft to float as many marbles as possible from any of 2 sheets of light card, 4 sheets of plastic, 8 straws, some tape and staples. The record was ~2kg of marbles!
Given a dozen bricks of wood of different densities (all bricks looked the same) build the longest extension possible from the edge of the table ~0.6m!

The less popular pair:
Lift as many staples into a plastic cup making contact with the staples only with the equipment provided, 2 large nails, a length of wire and 2 AA batteries ~145!
Obtain the period of a lighthouse based in a separate room using only a stopwatch of fixed location in the main laboratory, with no direct line of sight available.

An online shop aptly named 'I Want One Of Those' (www.iwoot.com) was very helpful: everything was delivered the morning after the order at no extra cost. The prizes were all gadgets with some physics or least scientific aspect. The preferred prizes tended to be suitable for throwing (Frisbees, throwing discs, phlat balls, zylos), or objects that make a noise (the more irritating the better). The lower price range ranged from pocket kites to gummy lenses for camera phones to puzzles to carry around on a keyring.

Evaluation and Improvement
The inaugural UPO was also run as a pilot to a new idea for Freshers' Week for the academic year 2006/07: therefore obtaining student opinion was very important on a somewhat hurriedly organised event. A final year project student in the Science Communication Unit, Mark Twigg, had the task of

independently evaluating the UPO. He employed several methods to find out what the participants in the UPO thought of the event (see note 1).

Qualitative Analysis
He attended the UPO to observe but did not participate. In his conclusions he refers to notes made at the time.
"The groups seemed to interact very well with each other and began talking very quickly."
"The groups all seemed to be having fun whilst taking part and soon built up a repertoire with the demonstrators as well."

Figure 2: The 3 nationalities of Team West make an electromagnet together

"The students seemed to be quite competitive and all really seemed to want to win each event."

He held some brief discussion groups immediately afterward and found two constantly repeated comments:
"it is difficult to get to know anybody new after the first few weeks of term."
"being able to work in a team is very important."

In the week after the event semi-structured questionnaires were given to the students with a very high response rate. The main questions asked them if they had enjoyed the event and had thought it was well structured. The most common replies included: "Enjoyed challenge/problem solving/meeting new people/fun/competitive/variety/limited-time a good element".

Quantitative Analysis
At a later date structured questionnaires were distributed for quantitative analysis.
Over 92% said 'yes' to the questions:
Was the UPO enjoyable?
Are you comfortable approaching people you met during UPO?
Was it easier to talk to demonstrators & staff?

While the response 'yes' was unanimous to the question:
Is it important to be able to work as a team?

The evaluation found that the event achieved its aims, and would be worth running again but during Freshers' Week followed by a social event. There was also substantial anecdotal evidence of improvement throughout the semester (see note 2). Perhaps the best indication of the pilot's success was that more than half the students who had participated presented themselves to help with running the UPO the following Freshers' Week.

UPO Freshers' Week 2006/07
As originally planned the UPO was rolled out full scale for Freshers' Week 2006/07. The format was little altered with only the minor changes suggested by the previous students. The students were treated to a buffet lunch, then teams were selected at random, though each group was allowed to pick their own team name.

The challenges which had initiated the least amount of teamwork (according to the evaluation) were dropped in favour of an outdoor event requiring students to move a metre stick a set distance (~30m) employing linear acceleration, and developing a code to pass a message successfully using only a drink can.

The quiz was revamped to include many specifically local questions, such as street names outside the Physics Department, incidents from recent news stories about physics and science, and naming the Minister for Science and Technology.

Improvement of small details helped smooth the running of events such as colour coding of paperwork for each section. The prize-giving was held immediately afterwards, which meant some very hard work by the judges to bring everything together, but it also meant that no one knew the winning team until the end. The students then invited the Freshers to an informal social event (i.e. the student bar), and the following day the Physics Society organised a fun social event outdoors. Approximately half way through the first semester all photos were put up on a student notice board, and the students reminisced.

Figure 3: Group photo after completing 4 events, bonus events and quiz in 3 hours

Discussion & Conclusions

The first UPO attracted ~60 students as it was run over more than one session and those scheduled for the later session had worked out that it was not compulsory. Therefore the students who turned up tended to be the more sociable outgoing students. The Freshers' Week 06/07 event was slightly hampered by a university event scheduled for the same time for some of our students which meant ~40 students participated.

In preparation for the Freshers' Week 2007/08 the new students will receive a brochure containing their schedule for the whole week. The UPO has been allocated 4 hours, and will begin with team selection, some icebreakers, followed by a buffet lunch and the main event, this time expecting ~90 students in one day. Staff are invited to the whole afternoon, though I would particularly like a staff team to enter at least one event. Again I have an over abundance of volunteers willing to help with the event, but as the challenges are all designed by students, I fear there will be a projectile challenge involved somehow!

In the longer term, if another Physics Department ran a similar type of event, I would consider hosting an event with teams from more than one university, but set a more scientifically rigorous problem for students to work on, to encourage the more adept students.

Notes:

1. *Investigation and Evaluation of the Undergraduate Physics Olympics* by M. Twigg. This is a final year thesis by a science communication student.
2. The laboratory sessions containing a majority of students who had participated in the UPO noticeably differed from the other sessions, as students tended to discuss experiments between themselves, approaching demonstrators only with meaning-based questions rather than the usual equipment-based ones. Also the tutorial attendance improved of those who had participated, and in general the year group were more willing to ask questions in large-lecture situations especially of those staff who had been present at the event.

Integrated Sciences

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... the solution to a curriculum that is both inclusive and challenging is to start from the interesting scientific problems. It doesn't matter if these are discipline specific or interdisciplinary.

Abstract
Science education seems to be diverging between an inclusive approach to general science and a contracting somewhat watered down discipline based approach. An inclusive but challenging curriculum should be based on real-world problems that are largely interdisciplinary. This will provide a virtuous circle of teachers enthusiastic about science communicating its relevance to their students.

Introduction
I would like to draw your attention to an interesting paradox. No-one in your Department knows more about your discipline than your newly graduating students. Of course, you are more of an expert on some aspect of your subject, but, unless you are very different from the academics I know, you would probably fail some of the options your undergraduates take in their stride, and in many cases some of the core too. Once they go on to research your students will also narrow their focus to the left eyebrow of the armadillo, on which subject they will give keynote addresses and enter vigorous e-mail dialogues with their fellow experts. Why do we insist that students start from a broader base than their teachers? The answer is so obvious I'll treat the question as rhetorical. But let me change the question a little. Why do we insist that the breadth of this base is so narrow? Why, when all the important issues facing the future of the human race are interdisciplinary, do we still engage in the discipline snobbery of an educational system that was designed primarily to produce the very best string theorists and quantum chemists?

While you are thinking that one out, I have a question from the opposite point of view: what do you think an anti-elitist approach to science education will do to recruitment of the best minds into science? Of course, we know the answer to this since it has already been the subject of a mass education experiment.

We appear to be caught in a classic pincer movement. On the one hand we desperately want science to be inclusive, not just for its own sake, but because we really need a scientifically literate community. And, on the other hand, we know that much of science cannot be simplified without it ceasing to be science, just as you can't leave out the left hand notes in a Mozart piano piece to make it simpler, without it ceasing to be music.

So what has emerged? We appear to be seeing the evolution of a two-tier system. On the one hand an approach based on the traditional disciplines of physics, chemistry and biology, somewhat watered down, but available, in the diminishing numbers of schools with specialist teachers, to just the few, most of who will opt in higher education for psychology, medicine and media studies rather than physics or chemistry. And, on the other hand, an imaginative Applied Science agenda offered, apparently, to those who can't do proper physics or chemistry and are not going to be scientists. I cannot believe that this is how the future was meant to be.

You may argue that another seven thousand brilliant physics and chemistry teachers will fix the problem. But, let's face it, that isn't going to happen, because the present curriculum is designed not to make it happen; nor should it, because the purpose of an educational system is not solely or even primarily to produce teachers.

To my mind the solution to a curriculum that is both inclusive and challenging is to start from the interesting scientific problems. It doesn't matter if these are discipline specific or interdisciplinary. It doesn't matter if these are problems of applied science and technology or purely intellectual puzzles. It does matter that they should be scientific issues, not sociology dressed in scientific clothing. It does matter that they are problems that can be tackled at several levels (not usually problematic in science). It does matter that they are problems, not solutions. The practice of science, as opposed to its reportage, is not about facts and answers, but about what can reasonably be said in the face of uncertain and incomplete information (something that it is very easy to replicate in the classroom).

Integrated Sciences

The IScience programme (see note) at Leicester which we started three years ago and has this year produced its first graduates, seeks to take this approach in higher education. Each specially written module in the programme is based on an interdisciplinary problem, requiring a detailed scientific investigation to offer a possible solution or response at various levels. Students are thereby taken to the frontiers of science across a range of areas in physics, chemistry, biology and earth sciences. This has now been taken up as a national programme, currently involving Surrey, the University of East Anglia and London South Bank University, under the banner of Integrated Sciences and under the leadership of the Institute of Physics, with HEFCE funding. This context has provided the imaginative missing link from the original Leicester programme: the option to transfer to the second or third year of a single discipline after 2 or 3 years of ISciences.

Some of the module descriptions will give a flavour of the Leicester programme. In the first year *Science of the Invisible* looks at chemical bonding, cell biology and the physical properties of solids, liquids and gases from a novel point of view, so that it is accessible and appealing to students with a variety of backgrounds which may include A-Levels in one or more of these disciplines. Furthermore, we do not aim for content coverage of all of the sciences, which would restrict the programme to a broad but basic level, but for a basis on which we can get to the research frontiers in a limited number of areas. *Forensics* is a second year module which requires students to act as expert witnesses in a murder mystery. (We get a law lecturer to play the role of judge in the final courtroom presentation assessment, with IScience staff cross-examining.) This is a good topic to include physics (time of death analysis from rates of cooling), chemistry (blood alcohol and drug analysis) and, of course, genetics. The *Earth through Time* in year 3 looks at many aspects of climate change. About this module one of our students comments:

> "I particularly enjoyed the final module of my third year on climate change. We looked at specific geological events, then moved to the IT suite to understand how you model these very hot or cold events. This helped us gain an understanding of climate modelling and prediction, a subject that's in the headlines all the time. The module was a great example of combining text-book knowledge, practical experience and access to leading experts in the field…. When I left school I really wanted to get involved in cutting edge research and I've achieved my ambition. My career options are really open."

"I particularly enjoyed the final module of my third year on climate change. We looked at specific geological events, then moved to the IT suite to understand how you model these very hot or cold events ..."

Thus we now have the model of an inclusive science programme that pays due respect both to the integrated nature of science and its discipline based specialist expertise. Rolling this backwards, we can see how a science programme in schools designed for the needs of the full range of student interests and abilities based on an interdisciplinary approach would provide the virtuous circle so absent from our current structures: a source of enthusiastic teachers with the morale to generate enthusiastic students. What seems to be lacking is simply the vision that science is not what you get when you dumb down physics and chemistry, but what all students, especially including the very best, should be engaged with as a preparation for a science-based world.

Note:
The original programme at Leicester was called Interdisciplinary Science and labelled i-Science for short. The national programme is called Integrated Sciences and referred to as ISciences. To develop some sense of brand image, we are in the process of dropping the Leicester hyphen and calling our degree IScience for short. All combinations work for e-mails and our web site.

Safe Labs for Science: an interactive approach to safety training

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Abstract

Safe working in Chemistry involves critical analysis, interactive thinking and the evolving application of risk assessment to procedure, reagent and environment. It also requires cooperation and teamwork. These are transferable skills that all scientists should possess, but safety training is too often presented to undergraduate students as a set of rules with little rationale offered to justify them. Attempts to go beyond a set of rules are frequently perceived by students and academics as tedious if not outright boring – however necessary they may be.

We describe the first stages of development of a safety training component for mainstream Chemistry courses that will allow students to identify safe and unsafe practices, undertake formal risk assessment, and enable them to improve the safety of their own environment. Our starting point is a Safety Training Workshop for our own 3rd year undergraduates, including case studies, a (competitive) team exercise (a lab 'scavenger hunt') and electronic self-testing, designed to alleviate the tedium. They also emphasise the cooperative nature of safe working and encourage teamwork – aspects which are normally neglected in degree programmes in Science. We also report on the positive student response.

Introduction

Good Laboratory Practice is not just a case of completing the paperwork and mentally ticking the 'safety box'. In a physical science subject where experimental research and observation are at the heart of the discipline, the skill set attained from risk assessment is a basic necessity. These skills are transferable but first require an innovative approach for their dissemination. In particular, one that is conducive to bringing about a change in mind-set for the average student.

Despite the effort exerted in safety training, students wait to be told rather than to think about safety information.

Throughout Ireland and the UK there has been considerable infrastructure investment in the refurbishment and building of university laboratories. In Trinity College, the arrival in 2000 of new research and undergraduate teaching laboratories raised the profile of safety in our departmental activities. Safety requirements, constraints and protocols were of primary concern in the concept and design of these new facilities. This new compliance however had not percolated down into the conscience of the student body and this is the universal problem that we hoped to address through an interactive safety workshop.

Course development

Despite the effort exerted in safety training, students wait to be told rather than to think about safety information. To encourage our third year undergraduate students (current cohort of 62 students within a 4 year degree programme) to begin to put into practice the safety training they have received up to this point in their academic life, we designed a one-day intensive safety course. What we needed was a hands-on, problem-based course directed at advanced undergraduate level which could be incorporated into the third year laboratory programme. We began our course with a lab scavenger hunt and self test electronic quiz. The second half of the course involved lectures in safety awareness, with examination of some scenario based events to make students aware of potential lab hazards. Deriving key information from Material Safety Data Sheets (MSDS) and how to prepare informative and up-to-date Risk Assessments were discussed followed by a lecture given by an invited speaker from industry in order to show that the importance of being safety aware is not just a university matter but can have significant industrial consequences.

Team exercises
One of the aims of the programme was to encourage critical thinking by our students in relation to good safety laboratory practice. In order to promote safe-aware thinking, students were split into small groups and began the day with a laboratory activity. This team building exercise allowed students to examine the safety features of the chemistry undergraduate laboratory including the location of fire exits, fire blankets and extinguishers, first aid kits and eye wash stations. The first exercise was to fill in a map of the laboratory, marking the location of all safety features and equipment. The second part to the laboratory exercise took the form of a lab scavenger hunt. Several experiments were set up incorrectly around the laboratory by some of the postgraduate demonstrators and students were asked to spot potential safety hazards. Examples of experimental setups used were distillation, column and reflux apparatus (Figures 1 - 3). Some of the hazards included glassware not securely fitted, electrical cables crossing hot plates, water tubing not fitted correctly to condensers, etc. Students worked in groups of four to complete the exercise, which included looking through the laboratory for any other breaches of correct safety procedures, e.g. unlabelled solvent bottles, glassware clamped incorrectly, etc.

We found this interactive approach was vital to making students alive to safety-considerations in a positive way. The team who identified the most number of hazards in the laboratory were awarded a prize. This competitive element to the groups' activities added to the enjoyment of the day and led to greater collaboration between students to identify all possible safety breaches in the laboratory.

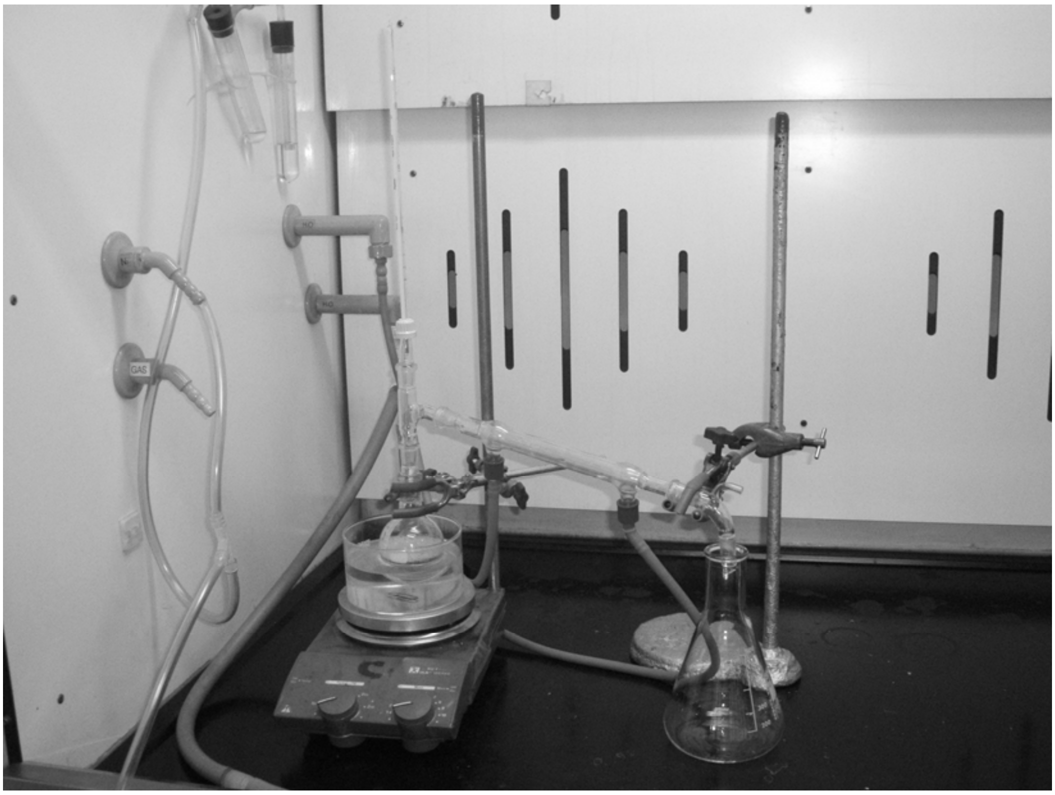

Figure 1: Scavenger hunt setup for distillation apparatus

Electronic Self-test
This was a computer based quiz, asking the students to answer 12 questions in 15 minutes. It was held at the start of the session to determine (or demonstrate) what the students did (and did not) already know, and to avoid the impression of it being an exam if held at the end. The questions covered both general matters (choice of fire extinguishers; identification of hazards and prioritisation of risks in experiments; choice of solvent) and more local matters (internal emergency phone number; assembly points etc). Scores ranged from 13% to 94% and the test was genuinely 'interactive' in that several of the questions (and our choice of 'correct' answers) provoked a substantial and sensible discussion from the students.

Safety lectures and case studies
Our afternoon lecture series began with a series of case studies designed to promote safety conscious thinking amongst students when it comes to protecting themselves against potential safety hazards. The lecture began with an examination of where our bodies are vulnerable to chemical attack and how chemicals may be absorbed by the body. Suitable clothing, such as laboratory coats, safety goggles and gloves were discussed. One case study used to illustrate the vital importance of protective equipment and the need to revisit and re-examine risk assessments of hazardous chemicals was that of Professor Karen Wetterhahn, who was poisoned by dimethylmercury, which seeped through the latex gloves she had been wearing. Even though Professor Wetterhahn followed all the standard safety procedures known at that time (use of labcoat, wearing safety goggles, working only in a fumehood and using latex gloves), the dose of mercury delivered to her body by one or two drops of dimethylmercury was enough to prove fatal. It was subsequently discovered that latex gloves did not provide sufficient protection against dimethylmercury and only heavy duty gloves should be used when handling this chemical. It was a wish of Professor Wetterhahn before her tragic death that her colleagues alert the scientific community to the

dangers of dimethylmercury. Inclusion of this case study in our safety day workshop not only makes students aware of the real dangers of mercury poisoning but also of the importance of wearing suitable protective clothing and following up-to-date safety procedures.

Likely laboratory accidents were also discussed with some real-life cases considered, including explosions due to incorrect solvent disposal. These cases highlighted the need for students to review safety data sheets before attempting to dispose of solvent or chemical waste. They also brought home to students the medical, financial and research costs of accidents in university laboratories.

The lecture on MSDS and Risk assessment was designed as a first step towards preparing students to work within a legal framework of risk assessment. Greater emphasis was placed on the existence of such a framework, rather then on the details of current national (and rapidly changing) legislation. The talk covered: hazards and risks; chronic and acute responses; contamination routes; getting information from labels, MSDS etc; and ended with the completion of our in-house risk assessment form for hazardous materials.

Figure 2: Scavenger hunt setup for column apparatus

The last lecture of the series was given by a visitor from industry, Dr. Michael Gillen, a member of the Health and Safety Executive from IBEC, who spoke of the importance of 'walking the walk' and not just 'talking the talk' when it comes to chemical safety. The students heard more real life safety scenarios, this time from industry, which cemented the notion that being safety aware is a concern for anybody working in a laboratory environment.

Student feedback and conclusions

The feedback we received from our undergraduate students was extremely positive, with most students commenting that their level of safety awareness had improved as a result of the safety workshop. The lab scavenger hunt was found to be one of the highlights of the day, with students noting they benefited from critically reviewing apparatus setups and would begin to do so with their own experimental setups. The team-building aspect of the exercise proved successful with some students remarking on the fact that they got to know their classmates better as a result of working together. Some students also reported that the use of case studies made the message of safety awareness stick with them. One suggestion the students made for change in the future was the inclusion of an interactive safety workshop as part of the laboratory curriculum for each year of undergraduate study in Chemistry. Students felt that this could act as a beneficial revision course to revisit some good safety practices each year. The workshop in fact allowed us to identify some material suitable for use in similar exercises for our first and second year students and we will be incorporating a 2½ hour workshop into the practical course for both of these classes from 2007-8. Since entry to the degree programme in Chemistry at Trinity College Dublin is via a common Natural Science entry, dissemination of these activities and the corresponding contribution to the academic development of the students across the Science Faculty is ensured. In particular, the School of Chemistry plays a pivotal role in the teaching of (one) Physics and (one) Biochemistry-related undergraduate degree programmes: Physics and Chemistry of Advanced Materials and Medicinal Chemistry. Thus, the advances we have made by implementing this safety training programme will impact positively on these disciplines.

The implementation of the workshop with third year students has also allowed us to invite our final (fourth) year project students to join in our postgraduate safety training day, run jointly with the School of Biochemistry and Immunology at the beginning of each academic year. The impact of doing so was

Figure 3: Scavenger hunt setup for reflux apparatus

uniformly positive – the senior undergraduates were pleased (and flattered!) to be invited, and the inclusion of this group of students contributed to the social and educational aspects of the day.

How to impart tacit knowledge: "Blending Chess and Chemistry"

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Abstract
Retrosynthesis has been likened to the game of chess. There are relatively simple rules to learn, but only through experience and practice can a learner acquire the tacit knowledge required for mastery of the subject. This makes it a challenging topic to teach effectively to a large and diverse cohort of learners. Lectures are a good way of transmitting knowledge, but do not provide the engagement and training that is essential in developing a deep understanding of retrosynthesis. Therefore, students tend to struggle to achieve success in this topic. This project aimed to alleviate this problem by producing online learning resources to be combined with traditional face-to-face teaching methods to develop a blended learning approach. These resources included animated videos, quizzes, worked examples and other interactive learning materials. Analysis of examination results and learner feedback showed that the supplementary resources not only improved student performance and understanding, but also provided a more satisfactory learning experience. External evaluation suggested that the learning package has significant potential and development should be continued. The package of learning resources can be viewed online at: people.bath.ac.uk/ch3jhm

The Challenge of Retrosynthesis
Retrosynthesis has typically been considered a very challenging topic by both students and lecturers. There are a number of reasons why this might be the case.

It is counter-intuitive, as it requires students to start from a target molecule and break it up, thinking backwards in a strategic fashion. This is the opposite process to all the organic chemistry they have previously learnt.

Retrosynthesis has also been likened to the game of chess[1]. In chess it is easy to learn how the pieces move so you can begin playing, but you cannot become a grandmaster simply by possessing this knowledge. You need practice and experience to develop a full understanding of the underpinning strategies. Similarly in retrosynthesis, you need to know the rules of how functional groups react to be able to design syntheses, but this knowledge alone will not enable you to carry out retrosynthesis on complex molecules. Again, practice and experience are required to formulate a deeper understanding and this cannot simply be passed on by an expert.

Retrosynthesis has also been likened to the game of chess. In chess it is easy to learn how the pieces move so you can begin playing, but you cannot become a grandmaster simply by possessing this knowledge.

As a result, the ability to perform retrosynthesis can be classified as tacit knowledge. This term was first used by Polanyi[2] to describe knowledge that allows an individual to perform a certain task, without that knowledge being easily transferred or learnt without the learner engaging in the activity. So, for retrosynthesis, it is not possible just to learn from lectures and textbooks, practice is essential to imbed the rules and theories learnt as an understanding of the topic and to help students develop the skills required to go with that understanding.

Current Teaching Methods
At the University of Bath, retrosynthesis is currently taught through a course of lectures, backed up by workshops and tutorials. Lectures are the most prevalent teaching method within Higher Education and are firmly imbedded within the traditions of university teaching[3]. Lectures are considered to be the most effective and efficient way of delivering content to large numbers of students in a short amount of time[4]. As a result, they are destined to remain an important part of the teaching within universities.

However, whilst lectures have been found to be an effective method of transmitting information, they are not as good for promoting thought or teaching behavioural skills[5]. They are also a passive learning experience, not giving students necessary opportunities to actively engage with the material and put what they have learnt into practice[6].

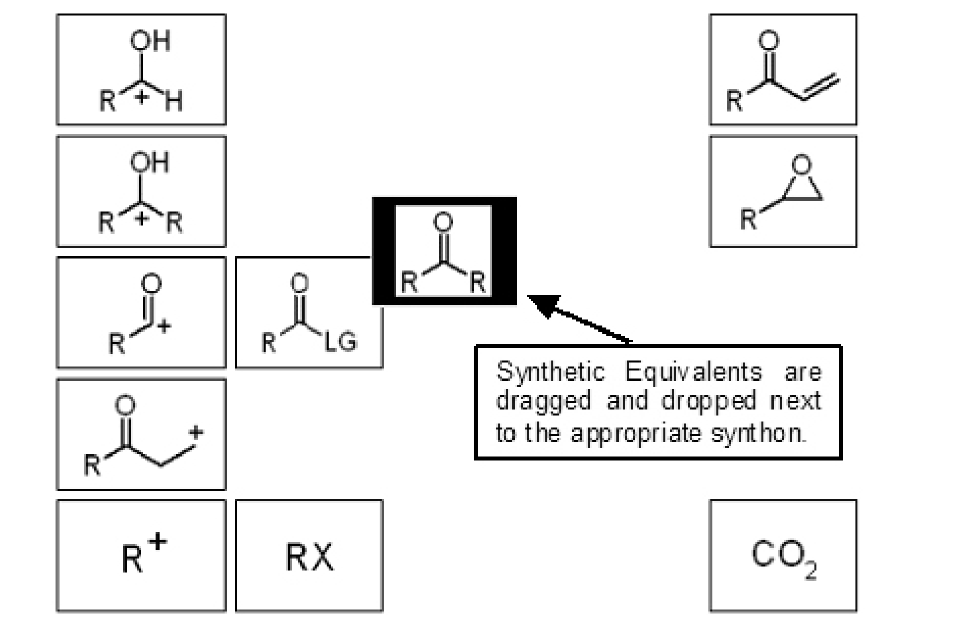

Figure 1: Example of Synthon Matching Quiz

It is therefore important to consider how the learning experience can be enhanced around the framework of lectures. For this project, consideration was given to how other teaching methods can be combined with lectures to enrich the learning experience for students. The main focus was on combining traditional, lecture-based teaching methods with online learning to provide a blended learning approach.

A blended approach can enhance the learning experience for students and improve their comprehension of a topic. Significant variety can be introduced into the learning materials that are provided, catering to the differing learning needs of students. The blended learning approach also allows flexibility in relation to both time and location, giving students the opportunity to learn at the pace and in the environment that they find most effective. Students enjoy greater control over their own learning, and are able to choose those resources that assist them most[7,8].

For this project, online learning resources were made available to students through Moodle, the virtual learning environment (VLE) supported by the University of Bath.

Project Aims

The project was divided into three sections: Exploratory Study, Resource Development and Development Study. The Exploratory Study aimed to identify the extent to which students struggle with the retrosynthesis course and the topics they find most problematic. The Resource Development stage involved the production of online learning materials to enhance the teaching and learning of retrosynthesis. The Development Study aimed to evaluate these resources from both a student and teacher perspective.

Exploratory Study

The Exploratory Study involved the use of workshops and tutorials to assess the understanding that students had developed during the normal lecture course and identify the areas that were most challenging. Students were asked to attempt retrosynthesis problems and their solutions were analysed. Through the answers students gave, observation of the student activity, the issues that were raised during the workshops, and informal student feedback, a picture of the problems students encountered and the topics with which they struggled was formed. A questionnaire was also used to obtain student opinions on their own comprehension and the resources they felt would be most helpful.

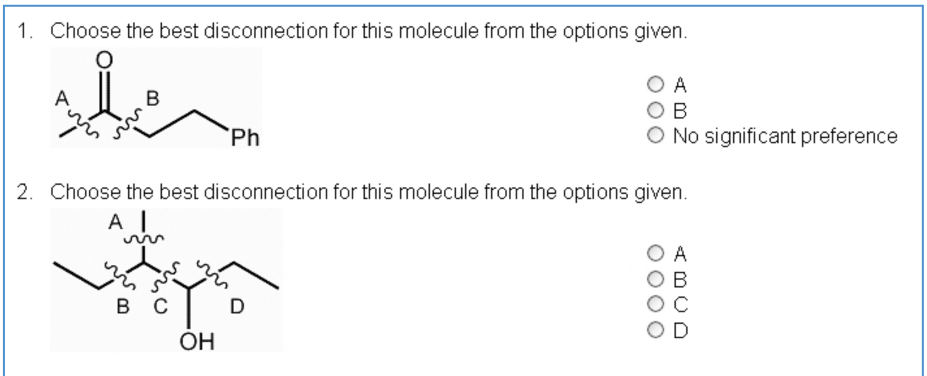

Figure 2: Example of Disconnections Quiz questions

Additionally, trial resources, including animated videos, were made available on Moodle and the students asked to give feedback in order to assess how such resources would be received.

The results showed that while students managed to grasp the basic principles of retrosynthesis, their knowledge and understanding was lacking in a number of areas, in particular the following:

- Remembering the synthetic equivalents to certain synthons
- Remembering reagents for FGIs (Functional Group Interconversions)
- Choosing the best disconnection to make to simplify a molecule
- Identifying selectivity issues

Therefore, these were areas on which the development of additional resources was focused. The initial resources that had been made available on Moodle were well received by the students. They liked and made of use of these resources and were positive about the usefulness, quality and pace of the videos. Therefore, videos seem to be an effective way of conveying concepts and working through question answers with students. However, support for the videos was not unanimous, and so it was important to include a variety of resources in order to cater to the learning needs of all.

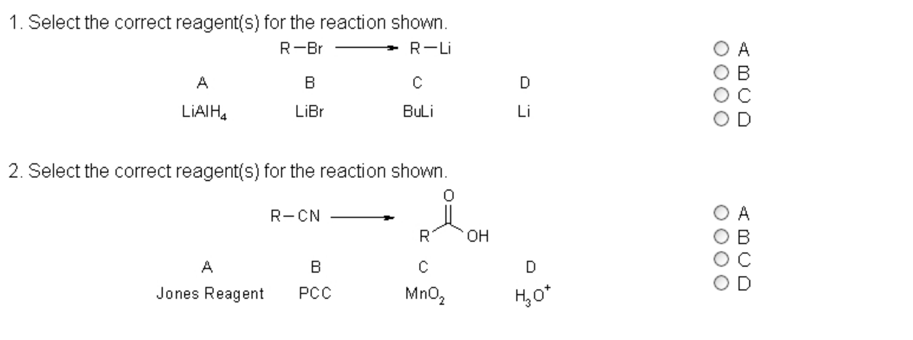

Figure 3: Example of FGI Quiz questions

Resource Development
At this initial stage of the project, resources for the first two lectures of a six lecture course were developed, along with some additional revision resources. The learning materials included the following:

- *Pre-lecture Lessons and Quiz* – a set of lessons covering the basic prerequisite knowledge for students to go through before participating in the lecture course, with a quiz to test their understanding of these areas.
- *Lecture Slides* – PowerPoint slides for use in lectures, around which the package is based.
- *Narrated Lectures* – the same lecture slides with voice narration added, so students could use them as part of an independent learning package.
- *Synthon Matching Quizzes* – quizzes that require students to match real reagents to synthons, to help them become familiar with these relationships – see Figure 1.
- *Disconnections Quiz* – a quiz requiring students to choose a disconnection from a number of options within a compound, to help them develop an understanding of the strategies for selecting the optimum disconnection – see Figure 2.
- *FGI Tool and Quiz* – a tool that allows students to find the reagents for carrying out a certain disconnection, with an associated quiz to test their knowledge – see Figure 3.
- *Worked Examples* – animated videos working through solutions, so students can see examples of how to tackle similar problems.
- *Practice Questions* – problems for students to attempt, with animated videos that take them interactively through the solutions, asking them questions on the way – see Figure 4.
- *Selectivity Videos* – animated videos taking students through the major selectivity issues covered in the course, with interactive questions to cement the understanding – see Figure 5.

Development Study
The majority of the resources were made available to students as they prepared for a summative assessment on retrosynthesis. A number of methods were used to ascertain the effectiveness of the resources from a student perspective, in terms of their opinions, usage and performance. These were Moodle user statistics, Moodle-based and paper-based questionnaires, student interviews and examination results. In order to gain a teacher perspective on the resources, academic staff from other Higher Education institutions were contacted and invited to evaluate the resources.

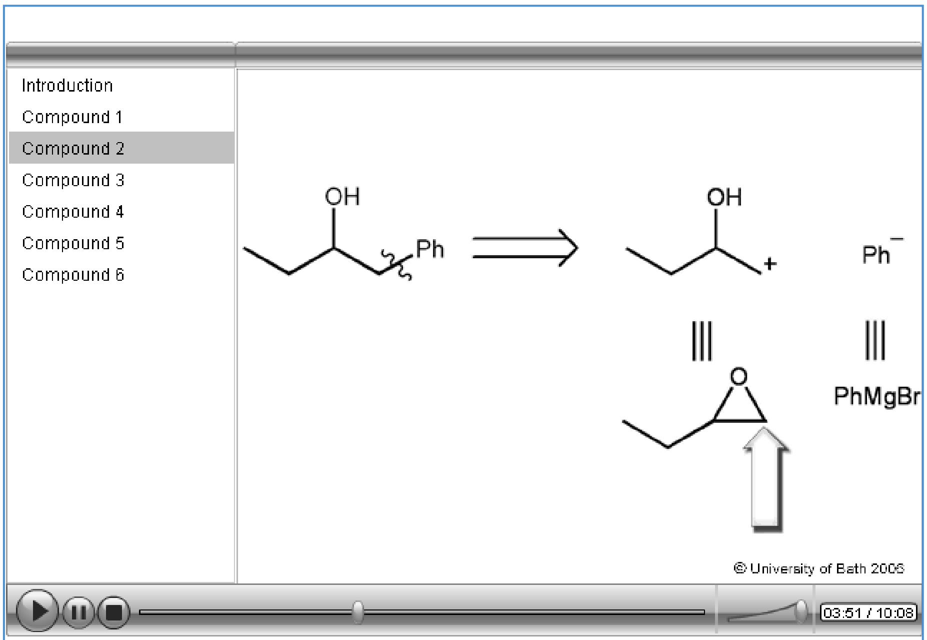

Figure 4: Screenshot of animated video solution to Practice Question

A significant improvement in exam performance was observed over the previous year, where no online learning resources were available. The average mark increased from 50% in 2006 to 68% in 2007. As Figure 6 shows, more than half of the students achieved a First Class grade in 2007, and fewer failed than in 2006.

There was a high uptake of the resources among students, with the vast majority making some use of them. Those students who used the resources performed significantly better in the exam, averaging 74%, compared to 50% for those students who did not make use of any of the resources.

The feedback received from students was very positive, and all the students who used the resources felt they had a positive impact on their exam performance. This was exemplified by some of the comments made by students, with the interactivity being highlighted as particularly important:
"The extra support on Moodle was helpful and much appreciated."
(Laura Fedorciow, BSc Chemistry with Management and SSLC Representative).
"The interactive format of this revision material was a welcome break from ordinary revision, and was much more effective than just reading the relevant information."
(David Cutcliffe, MChem Chemistry).

The external academic staff also rated the resources highly and felt the blended learning package would be of significant benefit to students learning retrosynthesis:
"I have lectured on [retrosynthesis] *for many years and I find this package very good…This package will help the students a lot."*
(Dr Paul Jenkins, Senior Lecturer, Department of Chemistry, University of Leicester).

They highlighted the importance of equipping students to continue studies outside lectures, in an environment they can control, but still with guidance and support:
"They allow students to go away and think out the steps needed for synthesis problems at their own pace – giving time for reflection which formal lectures do not give."
(Dr Hazel Wilkins, Lecturer, School of Life Sciences, Robert Gordon University).

There was unanimous support among the evaluators for the full development of the resources, but they identified a number of areas where improvements could be made and highlighted the need for a rigorous evaluation:
"What is needed are packages like this one that are then evaluated."
(Dr Bill Byers, Senior Lecturer, School of Health Sciences, University of Ulster).
"I would encourage you to continue with this development, we would certainly use it if it was available at a reasonable price."
(Dr Paul Jenkins, Senior Lecturer, Department of Chemistry, University of Leicester).

Conclusions

The process of learning is complex, and unique to each individual learner. Therefore, the task of imparting knowledge and promoting understanding in a large group of learners is a difficult one. It is made all the more difficult when the knowledge being conveyed is tacit in nature and the learners do not have a deep comprehension of the underpinning principles of the topic. This is the challenge faced when teaching retrosynthesis, which is akin to chemical chess, to a diverse body of learners.

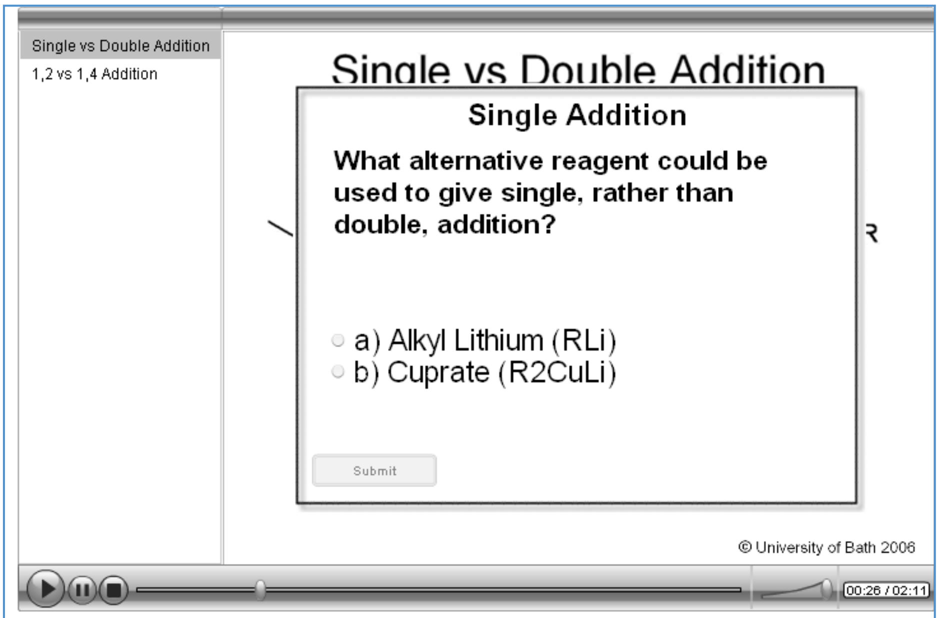

Figure 5: Screenshot of interactive question within a Selectivity Video

This research study has shown that success can be achieved by taking a blended approach to the teaching of this topic. The combination of face-to-face and online aspects of learning had significant positive effects on learners' understanding and ability to tackle retrosynthesis problems. Learners can engage more dynamically with the material and construct concepts on the basis of experience. The interactivity of the delivery methods increases motivation and focus, thus engendering more effective learning. Learners also benefit from extra freedom and flexibility to control their own learning.

The results of these enhancements to the learning process were two-fold:

- Improved examination performance, an indicator of comprehension
- Increased satisfaction with the learning experience

The positive results from the learner perspective were echoed by the feedback received from external evaluators. Individuals involved with the teaching of retrosynthesis suggested the blended learning package had significant potential and resource development should be continued. Therefore, it is intended that the development of this package will continue, and once complete it will be fully evaluated and made available to Higher Education establishments.

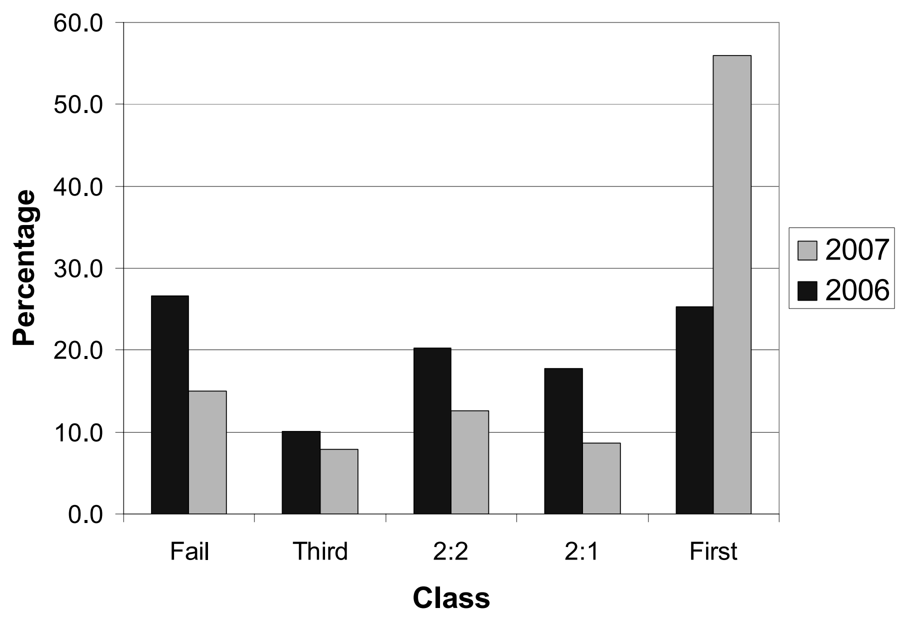

Figure 6: Bar Chart showing percentage of students achieving each degree class in the retrosynthesis exam for 2006 and 2007

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Improving Problem Solving with Simple Interventions

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While there are many excellent proven approaches for incorporating research based scientific teaching methods into the curriculum, many of them require an investment in time and energy to use effectively

Abstract
Although problem solving is a major goal for most science educators, many still rely on the demonstration method as an approach to teach it. This remains the case even though most are not happy with the results. Using a web-based problem delivery system to track students' performance, we have investigated the effects of collaborative learning, and concept mapping on student problem solving ability. We find that student ability in general can be improved by about 10% after a group problem solving intervention. Furthermore we find differences in improvement depending upon the students' level of logical thinking and gender.

Introduction
The improvement of problem solving abilities is a major goal of science educators[1], and a great deal of effort has gone into finding ways to improve these skills. Unfortunately and despite a growing body of research on how people learn and develop problem solving skills[2], many instructors rely upon the tried and true (or at least the traditional) method of demonstrating how the problem is solved and assigning similar problems for homework. Cognitive scientists tell us that knowledge is constructed by students and that skills must be developed by actively learning them rather than by watching another person's demonstration[3]. Yet faculty are slow to change their teaching approaches. Many faculty still give lectures about how to solve problems and then expect students to become expert problem solvers with no further assistance, even though a great deal of evidence (including students' test scores) indicates that traditional teaching methods do not result in optimal improvements in problem solving for many students[4].

When asked about the performance of their students, most faculty will say they are dissatisfied. Why then do they not implement some of the newer pedagogies that have been shown to be effective in the classroom? A number of possible explanations arise. Perhaps it is because faculty are unaware that there is a better way – much of the research has been reported in unfamiliar venues. Perhaps it is because some scientists are unconvinced by research that often relies on qualitative observations. Perhaps it is because they prefer to blame unprepared students. Certainly some of the fault goes to the reward system in higher education that is not geared to excellence and scholarship in teaching[5]. Whatever the reasons, it is incumbent upon faculty to use the best tools available to do the job. We need to approach teaching and learning in the same ways as scientific research, rather than relying on the status quo, opinion, and hearsay.

While there are many excellent proven approaches for incorporating research based scientific teaching methods into the curriculum[6], many of them require an investment in time and energy to use effectively. For a majority of faculty this change in teaching style may be difficult to accomplish given the time constraints and current reward systems. However, if we can incorporate relatively small changes into lecture based courses and observe real improvements, then the shift to more inquiry-based and active learning may gain momentum. One possible approach is collaborative learning, a widely used technique that can be employed in a variety of educational settings[7] and for which there is substantial research evidence to attest to its effectiveness[8]. For example: Mazur's use of Concept Tests[9] has shown measurable improvement in student understanding. Yet many faculty still do not introduce the relatively easily incorporated collaborative learning techniques into their classes.

Another simple intervention that can be used is concept mapping[21]. It has been reported that concept maps can provide students with a visual representation of their understanding of a given concept which in turn can promote metacognition[22] and motivate students to take the initiative to fill in gaps in their understanding. Research using concept maps has identified a relationship between problem solving and conceptual understanding. For example, Francisco and Nakhleh[23] reported the relationship between the quality of concept maps constructed and the performance on traditional chemistry problems.

In this paper we synthesise some of our previous research[24,25] on the effect of using a collaborative learning intervention on student problem solving abilities, and report a comparison of this with concept mapping as an intervention. Both methods are short and easy to implement – and result in measurable improvements in problem solving abilities.

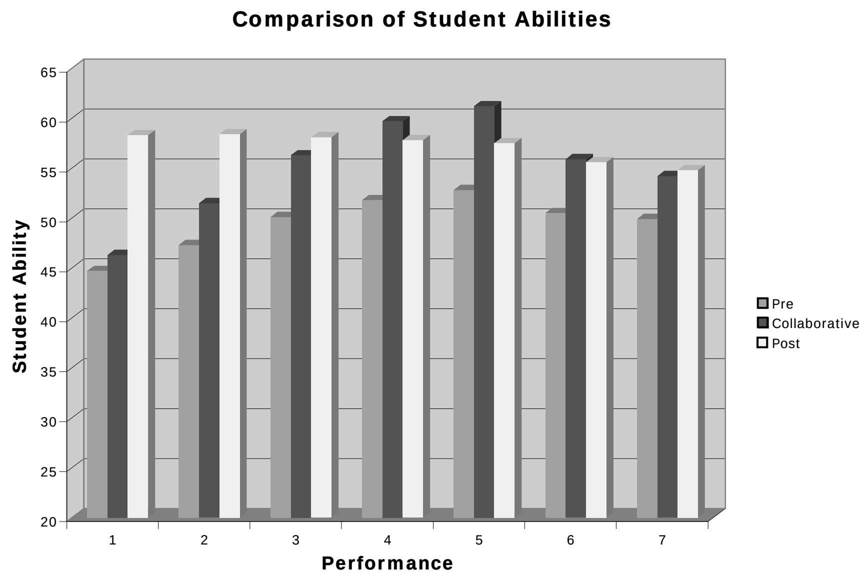

Figure 1: A comparison of student abilities for pre-collaborative, collaborative, and post-collaborative performances.

Experimental Methods

We have previously developed and reported[10-12] on the IMMEX (Interactive MultiMedia Exercises) system that allows us to deliver case-based problems to students and to track the sequence of actions that they use to solve the problem. The problems used in this study involve scenarios in which students must identify an unknown compound by choosing which tests to run and which data to use in the identification. One problem, *Hazmat*, requires students to identify the unknown; the other problem, *Lewis Structures*, used in the concept mapping study also requires students to identify the Lewis structure of the unknown. For each problem there are multiple unknowns and each requires a different sequence of tests and inferences from those tests. The unknowns are not all of the same difficulty: it is more difficult to identify nitric acid than sodium chloride. Therefore we cannot use percent correct as a measure of student ability. Instead we use Item Response Theory (IRT) which takes into account the difficulty of the problem as well as the probability that the student has arrived at the correct solution[13]; it is this student ability measure (which in our work ranges from 20-80) that we use in this report.

Research Design

Each study involved over 700 students who were enrolled in a general chemistry course at a southeastern research university. They were told of their rights as Human Subjects and completed informed-consent forms to allow their anonymous performance data to be analysed. All enrolled students were required to complete the assignment for course credit regardless of whether they gave permission for their data to be used.

Study1: *Hazmat*[24,25]

The goal of the study was to investigate whether allowing students to work in a collaborative group would improve problem solving abilities. Students were required to complete at least five problems individually, followed by five or more problems in a collaborative group, and then five or more individually. This pre-test, intervention, post-test experimental design was employed because it would allow us to compare the performance of students before and after the collaborative intervention.

We previously found[14] that students tend to stabilise on a problem solving strategy after performing fewer than five problems, and will continue with that strategy regardless of whether they are successful. We saw the same pattern in this study; that is, student abilities rapidly increased after the first problem attempt, and subsequently stabilised (Figure 1). Since these problems are quite complex it may take a student one or two attempts to learn to navigate the problem space and find the appropriate tests and information to identify the unknown. This finding is consistent with theories of skill acquisition[15]. Figure 1 shows that after the first three problem attempts the average student ability levels off (there is no significant difference between the abilities for performances 4 onwards). Previous studies have shown that the strategies adopted during this time are persistent and will be re-employed up to 3 months later[16].

After the initial group of problems were solved by students individually, the students were paired up and asked to perform at least five more problems. Finally students worked individually on at least five additional problems. The whole experiment extended over the course of several weeks. Figure I shows the abilities of the pre-grouping individual performances as compared to the group performances and the post-grouping individual performances.

As presented in Figure 1, when students work in groups the average ability rises rapidly and levels out after three performances, and **this improvement stays with the student after grouping**. Note that the final set of data for post -grouping student abilities are fairly constant, and all the post-grouping performances have a significantly higher ability ($p < 001$) than the fifth pre-grouping individual performance. It appears from these data that allowing students to collaborate while solving problems improves their ability, and that improvement is retained after the students return to individual problem solving. This finding is a direct rebuttal to those reluctant to allow collaborative learning in their classes because they feel the stronger students will dominate at the expense of weaker students. In this study we see that on average the improvement is about 6-7 units or about 10%. A question remains, however, about whether students of different intellectual abilities (as discussed in the following section) are equally affected by this intervention.

Students who participated in this study were also asked to complete the GALT (group assessment of logical thinking) test[17] which probes student understanding of proportional reasoning, data inferences and control of variables; all these skills are important in a science course. On the basis of their scores on this test, students were assigned to one of three categories of logical thinking based on Piaget's theories of intellectual development.
Formal: students are able to do proportional reasoning, make inferences from data, control variables and understand conservation of matter.
Pre-formal: students who are pre-formal may be able to perform at a formal level on some tasks and not on others.
Concrete: students' thinking levels are not fully developed; for example a concrete student is not able to reason from data, and may not be able to undertake many of the problem solving activities found in a college general chemistry course.

Previous reports[18] indicate that despite Piaget's original findings of formal thinking levels being attained by some as early as 11-14 years old, up to 50% of college freshmen students have not reached a fully formal thinking stage. In our study we found that 54% of the general chemistry students were Formal (F), 38% pre-Formal (P), and 8% Concrete (C).

Students were paired in all possible combinations (F-F, F-P, F-C, P-P, P-C, C-C) and asked to perform the same problem solving sequence as described previously, (at least five individual, five group, five individual). When individual student ability pre-grouping is compared to student ability post-grouping, a number of interesting trends emerge as shown in Figure 2.

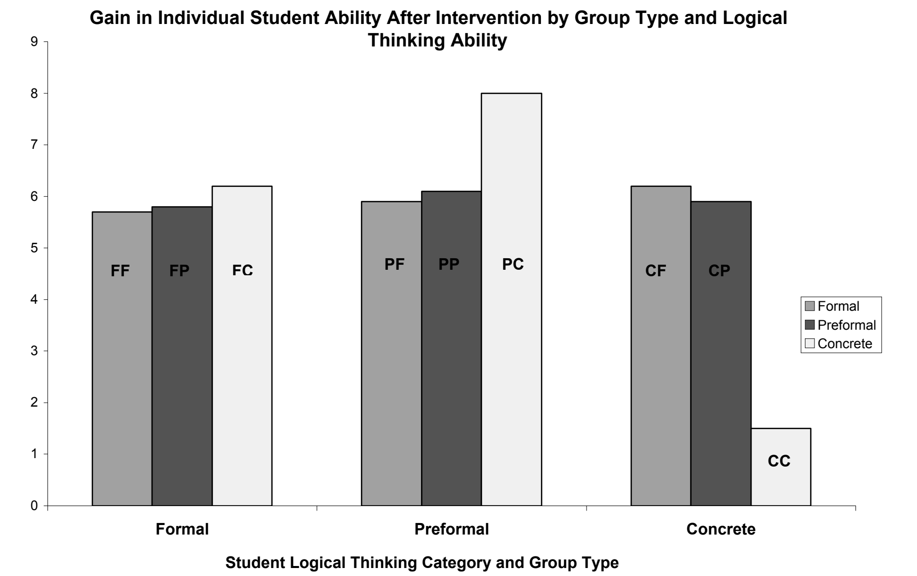

Figure 2: Gain in student ability for each type of group and the thinking level of the students in the group. The gain is statistically significant for every group at the p<0.001 level, except for the C-C group.

For most students the average gain is around six units (or 10% since the ability scale ranges from 20-80) which is statistically significant at the $p < 0.001$ level. When these data are viewed by type of grouping and student logical thinking level, however, two sets of data are significantly different from the rest. Groups consisting of two concrete students show almost no gain in ability after working together. For these students, who are not intellectually prepared for a complex problem, mere repetition and discussion of a problem clearly do not lead to increases in ability. However if concrete students are paired with pre-formal or formal students their gains are equal to those in all the other groups. Clearly concrete students paired with students who can explain the problem and discuss it with them can improve their problem solving performance.

The other noteworthy result is the gain in ability for pre-formal students who are paired with concrete level students, this being the only gain that is significantly larger than the average. A possible explanation for this finding is that, pre-formal students in these groups, are forced into the role of decision maker and teacher when paired with a concrete student. Our data provides evidence that pre-formal students can move into a higher thinking level. In fact, pre-formal students in a PC group have a final ability level of 56.5 which is identical to the final ability level of the formal students in any group. In contrast, the final improvement in ability for formal students following collaborative efforts does not appear to depend on the type of group in which they worked.

Furthermore, if these data are analysed by gender we see that most of the gain for pre-formal students emanates from the pre-formal female students as shown in Figure 3.

As can be seen, female students who are classified as pre-formal display marked improvements in problem solving ability after working with a group, although female concrete students do not seem to benefit in the same way.

<u>Study 2: *Lewis Structures*</u>
The goal of this study was to compare the effectiveness of collaborative grouping and concept mapping as interventions for problem solving. The study involved students in 45 laboratory sections with the labs being equally divided (15 for each designation) among *concept mapping*, *collaborative*, or *no intervention* (control). All students were asked to complete two Lewis structure problems. A week after completing them, the three groups of students were assigned in the laboratory either a concept map which was to be completed individually,

or a collaborative Lewis structure computer assignment containing two problems, or another assignment involving an unrelated problem. The collaborative group composition was heterogeneous and random. Students were given at most an hour to complete these assignments. After completing the in-lab task, each group was asked to complete four additional Lewis structure problems for homework.

Comparison of the abilities between the pre and the post-intervention assignment did reveal subsequent gains in student abilities for both the concept map and collaborative interventions. Gains were also observed with the control group, but this was expected considering students' prior exposure to this problem. The concept map group had the highest overall abilities following the interventions while the control group had the lowest.

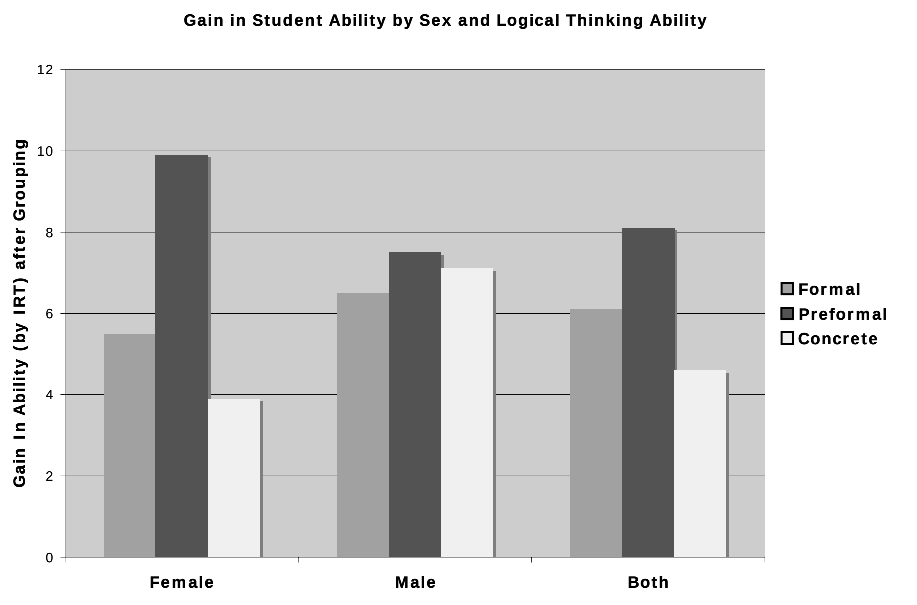

Figure 3: Gains in student ability after grouping, by sex and group type.

If the gains in student ability for males (Figure 4) and females (Figure 5) are viewed separately, we see an even more interesting trend emerge. It appears that different interventions are more effective depending on the sex of the student. For males, analysis indicated the post concept map abilities were statistically higher than either the collaborative ($p<0.01$) or the control ($p<0.01$) groups. That is, for males drawing a concept map was a more effective intervention than working in a collaborative group. For females, the opposite was true. The collaborative intervention lead to higher gains than the concept mapping intervention for females.

The observed gender effects may be attributed to the visual/spatial or verbal components of the intervention. Halpern[26] noted knowledge can be stored either visualspatially or verbally. Concept maps might promote visual storage by allowing one to connect the relationships among concepts and ideas in a diagram, while collaborative groups are more likely to promote verbal storage from the conversations and interactions that occur within groups.

Conclusions

Asking students to reflect on their thinking, either by discussion with others or by developing visual representations, while engaged in problem solving activities leads to improvements for most students, and these improvements are retained after grouping. That considered, the question remains: why do these methods have such a positive effect on problem solving, and why does this effect linger in subsequent performances?

An explanation surely lies in the fact that students are forced to become more thoughtful about their actions. That is group problem solving and concept mapping promotes metacognition[19]. Students must explain to their peers or themselves why they think an action should be taken and what the result might mean for their particular problem. It seems certain that most students can benefit from collaborative group work of this type, although students who are at a concrete thinking level should not be grouped together. The students who benefit most from this type of problem solving intervention are the female pre-formal students who are placed in a situation where they must take on the role of leader in the group. It is probable that these students become self directed explainers; that is they must explain to their partner how and why they are working through the problem in particular way. Chi has previously shown that this type of interaction tends to produce the highest gains in problem solving activities[20].

The differences between male and female responses to interventions indicates that, as in other teaching and learning activities, 'one size does not fit all' and a range of different interventions is preferable .

The most significant outcome of this research is that students retain their improvements and are better problem solvers when working independently after a simple intervention. The inference is clear: even informal collaborative groups, and short activities in which metacognition is encouraged, are a valuable tool in the teacher's arsenal. They can lead to measurable improvements in student problem solving ability in a relatively short time, and they can be easily implemented.

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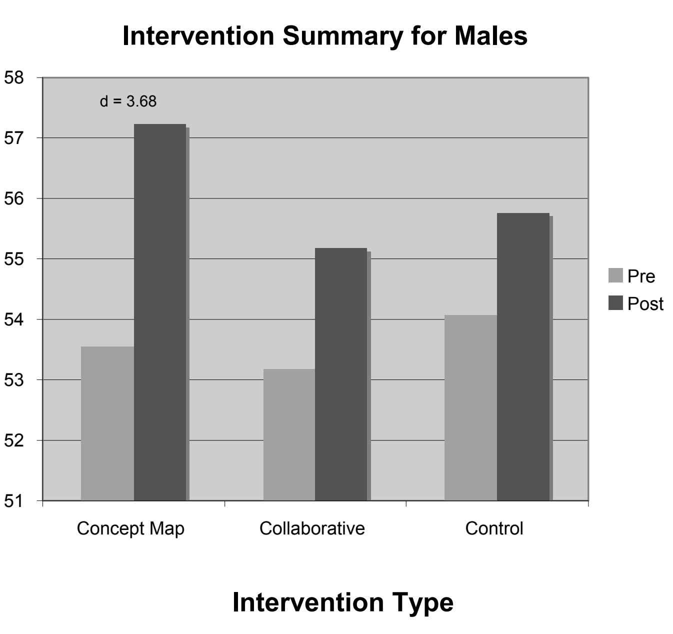

Figure 4: A comparison of the results observed for males. The 'd' values indicated above the bars indicate the gain in student ability between the pre and post assignments. The concept map intervention had the highest overall gain.

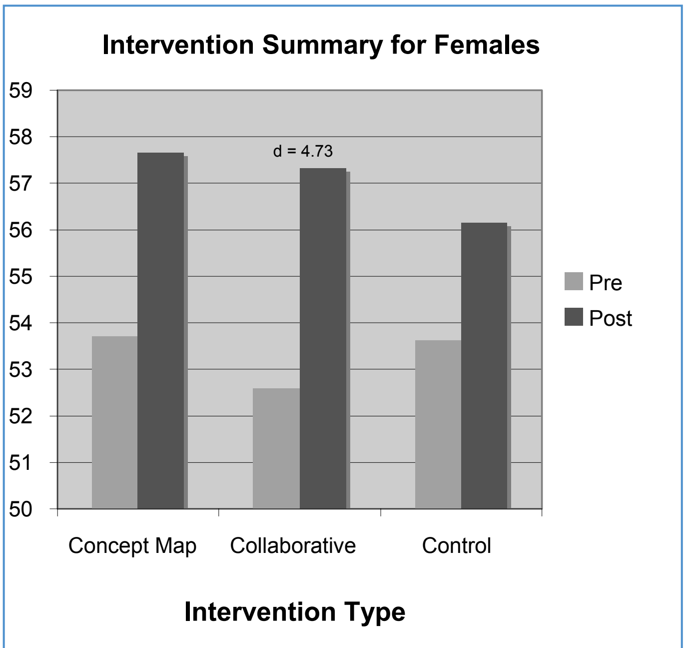

Figure 5: A comparison of the results observed for females. The 'd' values indicated above the bars indicate the gain in student ability between the pre and post assignments. The collaborative group intervention had the highest overall gain.

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Scientific abilities in undergraduate projects and laboratory

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Abstract
Projects are being increasingly used to provide a richer experience in physics teaching laboratories, and in the higher years, these may well approximate to the real world of industry and research. In first year, however, a wide range of approaches are utilised, from projects to open-ended experiments, yet questions remain about how students can best acquire a range of desired scientific abilities. Recent physics education research has suggested tools and approaches to help develop and measure the abilities such as needed to design and implement an experiment. Examples from several countries illustrate the need for matching the task with students' capabilities, and how various goals may be achieved for student learning in the laboratory.

Enquiry skills and laboratory
Skills of scientific enquiry have gained the attention of university physics educators in an unprecedented way in recent years. The May 2007 issue of European Journal of Physics has a special section dedicated to undergraduate laboratory and project work, in which several papers incorporated scientific enquiry. A similar emphasis is found in the other sciences. Some advances in research and effective practices will be outlined.

A study of learning and teaching in Australia's 34 university physics departments completed in 2005 showed a tenacious commitment to laboratory work in the face of substantially reduced academic staff and inadequate budgets[1]. Across first to third year, laboratory work accounted for between 25 - 40% of both student contact time and assessment weighting for most departments, with a few below 20%, and several more than 40%. Students' views of the abilities they gained in their undergraduate physics were obtained from focus groups comprising 118 students in 7 selected representative institutions, spread across first and third year and early postgraduate years. The majority of these students believed that they had obtained a lot or some of the following (in rank order, highest first): laboratory skills, problem solving, experimental design, written communication and teamwork. Since these skills are largely developed in the laboratory, it is reasonable to say that laboratory work was performing a useful role. Nevertheless, partly as a result of physics education research, partly by networking with others, many departments are undertaking initiatives to improve the effectiveness of their teaching laboratories[2].

In Europe, laboratory work in chemistry, physics and biology was mapped in a major study in the late 1990s, covering upper secondary and university levels[3]. The mapping was of content and processes, context, what students were expected to do in terms of actions and in terms of ideas, and included the degree to which students were required to take initiatives. Compared to chemistry and biology, the physics laboratory involved ideas and relationships between quantities to a greater extent, but had less diversity in the range of features. Physics laboratories were similar across national borders, causing the authors to speculate that this may not necessarily aid reflection, research and innovation today. On the degree of openness (open-endedness and student initiative), physics was the lowest, although all three disciplines were low at university level and close to zero at senior secondary level.

Projects and other possibilities
Experimental projects are, by their nature, the best way of preparing students for future work as scientists, engaging students and providing scope for their creativity. The piCETL project reported recently by Lambourne[4] and by Raine[5], are excellent examples of what can be achieved when a laboratory programme is transformed as part of a wider innovation.

Experimental projects are, by their nature, the best way of preparing students for future work as scientists, engaging students and providing scope for their creativity

Many Australian universities offer projects as part of their physics laboratory component, or as the whole of the laboratory programme for one or more semesters at higher years. Projects are also common as stand-alone subjects in third year, providing invaluable preparation for students intending to undertake further study at fourth year honours or higher degree. Such projects typically are added on after a traditional first and second year laboratory programme.

A major consideration in deciding on how to run a first year laboratory programme is the size of the class. The larger physics departments in Australia typically have between 200 and 500 students enrolled in mainstream first year physics, dropping to say 60-100 in the second year. Generally students take four disciplines in first year and narrow down to one or two disciplines at third year, so competition exists between disciplines to attract students, the better ones in particular. A balancing act is required, since the majority of first year physics students will not continue to third year, whilst on the other hand students may drift to other disciplines if laboratory work is uninspiring. In some Australian departments, project work at first year, which was considered highly valuable, has been dropped because of the cost and effort involved. Projects which have survived at first year typically involve teams in the construction of a particular device and take a large part or all of a semester's laboratory work.

Solutions to this dilemma include an advanced laboratory programme for selected students or an honours stream starting in first year. Mini-projects or open-ended experiments offer an alternative which may be offered to the whole cohort[2]. The Australian study noted that the current generation of students, who have grown up with technology and the internet, are likely to expect greater engagement and sense of contributing personally.

Scientific abilities and projects
Policies for secondary science curricula have raised the profile of scientific enquiry and both experts and teacher-researchers have looked at enquiry from many angles; useful mappings of scientific enquiry have been made[6]. Millar has reviewed the role of practical work in secondary science and cautioned against pinning too much on open-ended investigations. He warns that "attempts to include investigative practical work in the mainstream curriculum often result in practice that is disappointingly different from that intended, especially when students' performance of investigative tasks forms part of the course assessment"[7].

Policies for secondary science curricula have raised the profile of scientific enquiry and both experts and teacher-researchers have looked at enquiry from many angles; useful mappings of scientific enquiry have been made

In higher education, fewer are engaged in learning and teaching research. The curriculum, which has usually evolved from within the department, is likely to be less critically evaluated than at the secondary level. In addition, academic content and its level is a significant factor in student scientific enquiry. For these three reasons, it is understandable that scientific enquiry in higher education has been less thoroughly charted than in school science. A comprehensive survey of advances in (university) physics teaching across the international physics community in 2003 mentioned the need for 'discovery' in laboratory work, but none of the 392 references explicitly addressed inquiry skills[8].

A pre-requisite for successful outcomes in projects is an appropriate match of students' abilities to the set tasks, with useful guides for implementing project laboratory at first year by Planinšič[9], and suggestions for 'scaffolding' from students prior knowledge and experience by Neumann and Welzel[10] .

Our expectations for projects or open-ended laboratory need to be realistic. A long term study of student thinking and learning was observed in a range of university physics laboratory classes (by video-recoding of actions and conversations)[11]. To the surprise of the researchers, they found that "students in *all* studies rarely talked about physics concepts … rarely explicitly stated the principles … nor hypotheses". Rather the students typically search for a formula which leads to a suitable result. This is consistent with the typical novice approach to problem solving, and reminds us that scientific enquiry is a form of problem solving. They also noted that "the more open-ended the laboratory instruction, the less likely that students' activities will make explicit reference to physics concepts". Whilst this may arise from a weakness in the design of the activity and associated requirements (in terms of what is valued, what is to be discussed, or presented in a report), it is helpful to remember that students are finding their way through unfamiliar territory. The experiment and measurements are the concrete know-ables, so that working out the relationship between their observations and concepts may occupy only a small part of the time, but may be the most significant in terms of thinking and understanding.

Developing and assessing scientific abilities
We can consider two broad avenues for developing scientific abilities. One, akin to problem-based learning, is for the students to recognise the skills needed as they tackle the project or experiment (and acquire those skills). The other is to provide a sequence of structured small activities designed to cover the range of skills.

Etkina, van Heuvelen and colleagues[12] have over some years, generated an approach of the latter type for developing students' scientific abilities, and have produced tools for formatively assessing these skills. Their approach places a high value on experiments in learning physics[13], not simply as a better way for students to learn concepts, but as the way in which scientists actually work. The abilities are not restricted to the laboratory situation, but are developed in a holistic way through large classes and small group tutorials (recitations). They name the following abilities: "(A) the ability to represent physical processes in multiple ways; (B) the ability to devise and test a qualitative explanation or quantitative relationship; (C) the ability to modify a qualitative explanation or quantitative relationship; (D) the ability to design an experimental investigation; (E) the ability to collect and analyse data; (F) the ability to evaluate experimental predictions and outcomes, conceptual claims, problem solutions, and models, and (G) the ability to communicate".

Some of the model tasks provided by Etkina and colleagues are intentionally simple in order to suit students with no prior physics background; for first year students with good physics backgrounds other more appropriate tasks are available. The effectiveness of the approach for various abilities were tested in four projects, each across university large classes with different backgrounds, different reasons for taking physics and in different institutions.

Integral to their approach is the consistent form of tasks and processes which students work on throughout the semester. The experiments typically cover core topics in the introductory physics syllabus and students design an experiment to observe, or to test, or to apply, a given phenomenon. Student initiative is central, the tasks are relatively simple but often posed in an interesting way, for example, an exploration of how an object can be electrostatically charged without making contact, or the angle at which a toy truck can ascend a slope without slipping. The approach may be described as open-ended in relation to the experimental method, whilst the aim and equipment tend to be given. Students are required to reflect on what they did and learnt[14]. The rubrics used by instructors for formatively assessing students' work are also a tool for students' own self-evaluation.

In relation to their ability to design an experiment, little improvement occurred in students' recognition of underlying assumptions and awareness of the effect of experimental uncertainties. For these areas, further formative assessment tools are planned. It is worth commenting, however, on the imperative of addressing key skills within the laboratory class itself. If students' formative assessments are being written or discussed after the laboratory and away from the experimental environment, students are much less likely to appreciate tacit assumptions (e.g. that the floor is flat, in the case of one experiment cited). During the laboratory activity students are able to see the consequences of an unmet assumption (the ball not round or the table not horizontal or flat enough). The opportunity to make predictions and test assumptions is best utilised in the laboratory rather than in later imagination.

Steps toward improving enquiry skills

There are several ways in which scientific enquiry skills can be enhanced by relatively simple steps. One is to raise the level of student initiative in experiments which are otherwise basically unchanged in terms of equipment and conceptual content, by requiring students to make decisions about appropriate aspects of the method and the analysis of data. We have carried this out across most of our first and second year experiments[15]. In particular this can target the nature of the discussion, reflection or report required as part of the experiment, and address matters of science enquiry (for instance as utilised by Etkina et al). In addition to using this as a formative assessment tool (between demonstrator and student) we have expanded it as a follow-up exercise within small peer groups, the effectiveness of which is currently being evaluated. Recognition of the importance of formative assessment and self-evaluation has prompted us to replace a hands-on, end-of-semester practical test with formative assessment feedback throughout the weekly laboratory classes.

The 'Challenge Experiment' is one activity used over the past six years for first year main-stream students at Monash University which is specifically designed to extend students' enquiry skills and to inject some fun and interest.

The 'Challenge Experiment' is one activity used over the past six years for first year main-stream students at Monash University which is specifically designed to extend students' enquiry skills and to inject some fun and interest. Numerous other universities have used special experiments designed to achieve similar goals. Our students have two hours in teams of 3 or 4 persons, to experiment with physically interesting systems such as the precession of a gyroscope subject to an external torque; the rolling or slipping of a cable or cotton reel pulled by an attached string, and the oscillation of a magnet in an external magnetic field. They are in their second semester, and have had some 50 hours of laboratory prior to the Challenge. In their reflections written two weeks later, they responded to questions about what was special about the Challenge, and what they got out of it. Their open-ended responses showed a high level of appreciation of working out their own method, wrestling with a novel situation and achieving something themselves. They came to a more satisfying understanding than in a conventional experiment. In short, this two-hour experience achieved many of the positive aspects of an extended project, though clearly not to the same extent. Among the students who continued to second year Physics after its inception, the Challenge experiments (including a simpler semester 1 activity) stood out as the favourite components of first year physics[16], and has probably been a positive factor in our increased number of students continuing in the second year.

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Whilst changes to the A-Level system have been fundamental the subject content and level of achievement for GCSE Mathematics ... has remained more or less static.

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What's in a grade?
The real meaning of mathematics grades at GCSE and A-Level

Abstract
The scheme of work in mathematics and science subjects at GCSE and A-Level has been constantly changing over the last fifteen years. Under the auspices of a pilot scheme funded by Chemistry for our Future (CFOF) we review the current scheme of work in mathematics at both GCSE and A-Level from the three main examining boards and provide insight into what mathematical skills one might expect from a student entering a Physical Science degree programme, in particular in Chemistry.

A-Level Mathematics (Background information)
Prior to 2000 students traditionally followed A-Level courses which were:

either	Pure Maths 50%	+	Applied (Mechanics)	50%
or	Pure Maths 50%	+	Statistics	50%

The depth of study was relatively intense with some fairly rigorous calculus and formal proofs. For example in Statistics students were expected to be able to derive the Normal Distribution mean and standard deviation using calculus learnt within the Pure section of the course. Whilst all students received a solid grounding in Pure Mathematics they usually studied only either Mechanics or Statistics (albeit to some depth).

Post 2000 the new A-Level system for all subjects came into force based upon 6 modules for the full A-Level. Structurally it was as follows:

Pure Maths 50%	Applied Modules 50%
3 modules P1, P2, P3	3 from Stats, Mechanics or Discrete

The advantage of the new system was that whilst retaining most of the traditional Pure content it enabled students to broaden their Applied content (albeit at a cost of depth). However, it quickly became apparent that students were finding the new structure and content difficult. Results dipped dramatically and exam boards responded by reviewing the whole structure again and temporarily offering an extra examination session in November for students wishing to retake modules. Mathematics was the only subject forced to do this. The current structure is now as follows: (see appendix for detailed content)

Core Pure Maths	66.6%	Applied units	33.3%
4 modules C1, C2, C3, C4		Combination of any two S1, S2, M1, M2, D1, D2	

Students studying Further Mathematics have considerable freedom in their choice of Applied units but it is compulsory to take the Further Pure 1 module. The current A-Level system is again under review with a move to a four module system. However, Mathematics and the Science subjects are not included in this restructuring. We expect the six modules to be with us for some time yet.

Background information: GCSE Mathematics
Whilst changes to the A-Level system have been fundamental the subject content and level of achievement for GCSE Mathematics (at least at the Higher Level) has remained more or less static. However, structural changes have been made.

2008	First examination of the new two tier GCSE (Higher and Foundation). Currently Maths is the only subject operating at three tiers.
2008	Last examination involving coursework. Currently coursework comprises 20% of the overall total.
2010	A 'Functional Maths' element is proposed to be incorporated into the GCSE. Pilots are on-going at the present time.

Note: Mathematics is the only subject where students have to work at a level above GCSE in order to gain an A* grade for their coursework.

GCSE Subject Content
Content for GCSE Higher Level courses is virtually identical across the various examination boards. The main differences occur in the delivery of the course which may involve one examination period, or the modular approach with students taking individual modules at set periods during the year.

It is also common to see differences in approach towards coursework with some boards offering set problems which can be assessed either by teachers or by the board. Some options allow schools to set their own coursework tasks which are then marked against set criteria. The new non-coursework GCSE which comes into operation in 2008 retains the content of the previous GCSE, but is to incorporate questions within the examination which directly assess the old coursework elements such as data handling and investigations.

Mathematics is the only subject where students have to work at a level above GCSE in order to gain an A grade for their coursework.*

Students applying for University degrees with an element of mathematics involved would have needed to have followed the Higher Level course at GCSE.
Students following an Intermediate level course (2007 is the last year anyhow!) will not have the depth of algebraic knowledge required. Very occasionally students have successfully taken an A-Level in mathematics having followed the Intermediate GCSE course, but it is a rarity and they have had to work hard at upgrading their skills.

Summary of Higher Level content **relevant** to a Chemistry Course

Solving numerical Problems
Percentages
Surds
Standard Form
Exponential growth

Ratio and proportion
Powers, fractional, inverse

Equations, formulas and identities
Transposition of formula
Factors, linear and quadratic
Index notation
Solving equations
approx solutions
Formula substitutions
Simultaneous equations
Quadratics, use of formula + completing the square

Sequences, Functions, Graphs
Coordinate geometry: use of Y=mX + c, parallel and perpendicular lines
Interpreting graphical information
Graphical solution to equations
Graphical transformations of functions
Vectors: basic definitions + vector geometry
Trigonometrical graphs + basic trig functions including use of Sine, Cosine rules
Bearings, Simple Loci problems.

In addition, the data handling section of the course containing elements of basic statistics, probability and simple data analysis will be included.

Assessment of student capabilities at A-Level

<u>AS-Level</u>

Students entering university with AS-Level mathematics often polarise into two categories:
a) A strong student who started 4 or more A-Level courses but dropped mathematics at the end of year 12 to concentrate on the other subjects. Likely to have obtained a strong grade.
b) A (mathematically) weaker student who managed to take their maths knowledge a little further than GCSE but have now reached their limits.

Grade A/B candidate
Likely to fall in the category (a). A candidate with good all round algebraic skills and able to take on new concepts quickly. However, there will be a lack of depth in areas such as calculus and trigonometry. They will be familiar with the concepts of differentiation and integration but only at a basic level.

Grade C candidate
Algebraic skills much less well developed and often these students have obtained the majority of their marks from the Applied section of the course. No great depth to their Calculus knowledge and students engaging upon a university course containing a substantial mathematical element will initially struggle.

Grade D/E candidate
As above but to a greater degree. The algebraic skills are likely to be fairly basic and this student would have to work very hard to keep pace with the demands of any mathematical content.

A-Level

Grade A candidate
Obviously strong mathematically with good overall skills. Their algebra and calculus in particular will be a strength and there will be a depth of understanding. Students will have a clear knowledge of Algebra courses at university, except for the sections on matrices, complex numbers and some elements of expansions.

Grades B & C
Mathematically quite good students but likely to have lower capabilities at the top end of the A-Level Core content. For example some of the more difficult work on trigonometry and integrations requiring a substitution will be at the upper end of their abilities. Students obtaining these grades at A-Level often have very good marks for their Applied modules e.g. Statistics or Discrete maths and high marks for the first two Core modules. The more in depth Core 3 and Core 4 modules are less well attempted.

Grades D & E
Generally students obtaining these grades will have found much of the Pure content of the A-Level quite demanding. Quite often their marks will have been boosted by solid performances within the Applied modules and a relatively easy Core 1 module. They will have struggled with the later Core 2, 3, 4 modules. Students obtaining a low grade A at GCSE or grades B and C will often fall into this category.

Further Maths
Any student successfully completing the Further Maths Course is by definition a very capable mathematician and well able to cope with the mathematical demands of a university chemistry course.

Any student successfully completing the Further Maths Course is by definition a very capable mathematician and well able to cope with the mathematical demands of a university chemistry course

Scottish entrants
Students following the Scottish Boards syllabus content will have covered similar topics to their English, Welsh, and Northern Ireland counterparts. However, the structure and standard of question papers do differ considerably from the standard A-Level. A rough comparison between syllabus content and standard (at least for mathematics) would be the Scottish Higher qualification to be slightly above the AS-Level. The Scottish Advanced Mathematics course has content which features most aspects of the standard A-Level but also incorporates elements of the Further Maths A-Level.

Assessment of student capabilities at GCSE level
Students applying for university courses where a GCSE is their highest qualification in mathematics will, in the main, not have studied the subject to any great extent for two years. Their mathematical skills will probably have not increased but will have diminished over this period. **It is a strong recommendation that only students taking Higher Level GCSE courses be considered.** Basic calculus and the more advanced algebra is the minimum required for Physical Science degrees at University. For students without higher level GCSE the step up to improve their mathematical knowledge upon entry to University is considerable.

Grade A* Students
These students will have good algebraic skills and be capable of manipulating formulae quite easily. They will not have seen the use of complex numbers or logarithms. Calculus will be almost entirely foreign to them. However, an 'A*' student is mathematically capable and provided sufficient support is given they should be able to upgrade their skills to a sufficient level.

Grade A Students
These students will be competent mathematicians but not intuitive. The range of abilities from just missing out on an 'A*' grade to just scraping an 'A' grade is considerable. It is often the case that students are able to gain an 'A' grade through sheer hard work but they are approaching the limits of their mathematical abilities. The role of coursework is often critical with hard working students able to move into the grade 'A' on the basis of good coursework. An 'A' grade student will have reasonable algebraic skills but may not necessarily be comfortable with the detail required at later stages of the course.

Grade B Students
These students (**which could include Intermediate candidates**) will have a general level of ability in mathematics. For example they will be able to evaluate problems involving basic percentages comfortably, work with standard forms, or solve simple equations. They will not be strong algebraically and they would find topics such as basic calculus very hard. A student, at this level, applying for any University course involving an aspect of mathematics would find the prospect very daunting.

Grade C Students
As for a grade B but to a greater extent. Algebraic skills are likely to be poorly developed. A student with a grade C, will struggle with basic calculus and advanced algebra.

On-going work

As part of a pilot scheme for *Chemistry for our Future* we have reviewed the content of the current schemes of work for GCSE and A-Level mathematics and given indications of the mathematical ability of candidates at each grade. We would be delighted to review the mathematical content of any courses in the Physical Sciences and map grades in mathematics at GCSE and A-Level to them, so that course conveners can determine where the cut offs might be for their supplementary courses and the topics that should be included in them: send a list of the mathematical content to the following e-mail address Karen.Shallcross@bris.ac.uk and entitle the e-mail **ND-CFOF maths**. We are also in the process of surveying mathematics provision and content in Chemistry at tertiary level and will be producing a report on our findings in September 2008.

Acknowledgments

We thank CFOF under whose auspices this work was carried out. We thank Gareth Price and Simon Bedford at Bath University for their support and useful discussions and Tim Harrison and Karen Shallcross at Bristol University for their contributions to this work.

We would be delighted to review the mathematical content of any courses in the Physical Sciences and map grades in mathematics at GCSE and A-Level to them

The impact of Teacher Fellows on teaching and assessment at tertiary level

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Abstract
It is perceived that Outreach activities are primarily conducted to raise the profile of the department and the subject with a view to recruitment. However, we highlight a range of benefits to teaching practice and assessment of practical teaching at tertiary level that can arise from such activities. In particular, engaging with secondary school teachers can provide invaluable insight into successful teaching and learning strategies in particular for first year undergraduates.

Introduction
Bristol ChemLabS is a HEFCE CETL that has dedicated significant resources to its Outreach program to secondary schools and the general public. One of the main components of the program has been the appointment of a full time School Teacher Fellow (STF) Tim Harrison for the duration of the CETL project. The advantages such an appointment brings to Outreach activities are discussed by Shallcross and Harrison[1] highlighting the effectiveness of such activities, particularly to schools. The potential benefits of a good outreach program in terms of promoting the subject and in the long term recruitment to the subject are obvious. However, are there other direct benefits to a department from such endeavours in terms of teaching practice and assessment? After two years of our outreach program we reflect on some possible benefits.

Benefits to Teaching at tertiary level
Having a STF in the Department has had a significant impact on undergraduate teaching. The STF has discussed courses, sat in on lectures and most importantly had an input on the design and implementation of 1st year practicals. It is easy to discuss the content of a first year course with a resident STF and to be made aware of material that will be totally new and of course to know what students should already know[2]. Two groups in particular have benefited from involvement with the Outreach program in terms of their tertiary teaching.

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Benefits to Academics
For the academics involved in Outreach activities (about 30% of staff) it has been an opportunity for them to interact with secondary school students and the general public, something Barnes[3] implores us to do. In particular working with a range of audiences (such as adults with visual impairment) and over a range of timescales (from the 10 minute presentation to the day long activity) has challenged them to rethink teaching strategies and to engage the full range of senses in lectures and workshops and in particular not to immediately construct a PowerPoint presentation. More lecturers have developed practical or computer generated demonstrations for outreach purposes and this has encouraged them to use demonstrations in lectures and break out from the 'safe' PowerPoint or chalk and talk presentation. Perfumers smell sticks have been used on occasion! Informal and formal feedback from undergraduates has shown their appreciation of this effort and there is evidence from interactions in workshops that well thought out demonstrations have aided student cognition.

Giving subject updates to secondary teachers has been a very valuable experience for the academics let alone the teachers. They have provided real insight for the academics highlighting those subject areas that are difficult to grasp and why. Through interaction with secondary school teachers academics have been exposed to different teaching styles themselves and strategies for teaching difficult topics. This has been a powerful way of refreshing the link between tertiary level and secondary level teaching.

Benefits to Postgraduates
Postgraduates make a vital contribution to the Outreach Program. In surveys they highlighted several benefits of involvement in Outreach. These included: giving

presentations of their research to a wide range of audiences, writing articles for journals targeted at schools and working in practicals with the complete range of young people of school age. They found that this forced them to understand the background to their research and they were often challenged by interesting questions that sometimes brought new perspectives to their research. Some postgraduates are involved in supporting the delivery of workshops to undergraduates; they found the outreach program a very useful launch pad into honing teaching skills. In addition, working with a secondary school teacher provided many useful insights into teaching strategies, something that is also true for academics. Being praised by school teachers and the general public for a job well done has excellent benefits for the individual and department in terms of teaching and demonstrating confidence and quality.

The Approach of the Outreach Program and its impact on practical assessment

Often evaluation of an undergraduate course involves a questionnaire completed either in a few minutes at the end of the course or perhaps some time after the course has ended. Some of the feedback can be useful but a lot is not. The use of focus groups is a very valuable way of obtaining feedback and improving evaluation and is used at Bristol. But are there other ways that we can capture useful information on teaching to inform practice?

In the outreach program we take the view that we do not want to hand out questionnaires to students before they start an activity and then on completion of the activity to find out whether it has done what it set out to do. There seems no poorer way to begin an enthusing activity and it is hardly the way to conclude an event. The questionnaires are often completed hastily because the accompanying teachers wish to leave quickly. Are the answers to the questionnaires what the participants really think or are they what they think you want to read? Is there sufficient time for reflection set aside for filling in the evaluation forms? Think back to your own attendance at a recent workshop or conference and your own attitude to the inevitable course survey. Some surveying using questionnaires is valuable, but what else can be done?

It is useful as a starting point to consider why Outreach providers should obtain feedback on their events. We suggest that there are several reasons. First there is a need to find out where an improvement could be made in an event that will be run again. Secondly, it may be a requirement from a funding body to assess the impact of the event. Thirdly feedback may provide numerous quotes that can be used in articles, web pages, presentations and possibly in future grant applications. Lastly, and hopefully, there is the 'feel good' factor of a job well done by all those concerned. Are questionnaires to students the way to elicit this information?

In the case of laboratory work we invite demonstrators to comment on unclear instructions, as they are the ones likely to be asked for an explanation repeatedly. They will be able to judge the level of engagement with the task(s) in hand. They will also be able to offer constructive suggestions for improvement of text, practical layout and timing. Such feedback from demonstrators during undergraduate practical teaching has been a powerful evaluation mechanism.

Questionnaires given to accompanying teachers are also invaluable. In most cases questionnaires given to teachers early on in the activity, so that they are aware of the areas to look at, will yield more useful information than ones given at the end of the session, when its return can not be guaranteed. Teachers can also be asked to comment on the level of the activity in relation to the ability of the participating group and to its appropriateness to links within the subject specification. Since there is often considerable cross-over between Post 16 and 1st year undergraduate practical work, we have had much useful advice from secondary school teachers which together with their evaluation of practical procedures and practical scripts, has benefited undergraduate work.

The expertise of technicians is also sought to inform future practical outreach events. Whilst good events will already have involved the technical staff in the planning stages, their thoughts on possible improvements should be captured fairly quickly afterwards whether this is adjustments to numbers, sizes or types of glassware, positioning of stock bottles or in the issuing of laboratory coats. Indeed, technical staff form a very valuable part of the evaluation of undergraduate laboratory sessions.

Summary and looking forward

Working closely with a range of secondary school teachers can have significant benefits in terms of informing Teaching and Learning practice, and evaluation of practical teaching, in HEIs. For many years at Bristol we have had a Teaching Advisory Board, composed of secondary school teachers, that meets once a year to review topics in Chemistry and aspects of teaching and this has been of great help. However, having a regular flow of teachers through the department throughout the year has been very beneficial to academics, postgraduates and technical staff, in particular in the area of practical Chemistry.

The concept of a School Teacher Fellow has been taken up by the *Chemistry for our Future* Pilot scheme and seven STFs will be working with Chemistry Departments in Bath, Nottingham, Leeds, Warwick, Birmingham, Sheffield and Reading, together with TGH at Bristol and David Read at Southampton funded under separate schemes. Some of these STFs will also review first year undergraduate courses in their respective departments in 2007-2008.

Acknowledgments

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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 2008, to the editor...

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The deadline for full articles is 30th June 2008.

This is your chance to contribute to 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.

Style guide for contributors

These notes are a guide for those preparing contributions for New Directions.

They are not intended to be mandatory but using them facilitates production.

The notes cover the major areas of the formatting used *in-house*.

General
Contributions should normally be submitted as email attachments from a wordprocessor (although other submissions may be acceptable).

Text
Text is aligned left, with a single line space, and no additional space added before or after paragraphs. Paragraphs are not indented but between paragraphs there is a single line space.

Titles for contributions are Century Gothic, 18pt, Academy Blue (R77: G144: B205).

Normal (body) text is Arial, 9pt, black.

Main headings within the text are Arial, 9pt, Bold.

Abstracts are in Arial, p9t, Italic text.

Contributor information is in Arial, 9pt, Bold text.

Bulleted and numbered lists are aligned left with subsequent text indented by 0.25 inches.

References
References in the text should be denoted via superscripted numbers.

References should be listed at the end of the contribution in the format shown in the following examples:

1. Polanyi, M. (1962) Tacit Knowing: Its Bearing on Some Problems of Psychology, *Reviews of Modern Physics*, **34** (4), 601-616.
2. Laurillard, D. (1993) *Rethinking University Teaching: a framework for the effective use of educational technology*, London: Routledge.

Images
Images should normally be supplied separately (as email attachments) in a high resolution format as jpeg or gif files (although other formats - eg inline graphics - may be acceptable), with legends. Images will be rendered to grey-scale for printing.

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