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New Directions

in the Teaching of Physical Sciences

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Editorial

New Directions focuses on new developments by practitioners in the field of learning and teaching, and is produced by the Physical Sciences Centre in association with πCETL, The Physics Innovations Centre for Excellence in Teaching and Learning.

In this issue we have a review of epistemological beliefs. Communications cover a range of physics sciences education topics including the outcomes of the RSCs *Chemistry For Our Future* and two communications from CETLs, one of which outlines their achievements since their inception. Other areas covered include public engagement and science outreach, topics which have featured prominently in previous issues; problem based learning, another popular topic; diagnostic tests; the setting up of an image bank and student transition.

Our thanks go to those who have contributed to this issue and we would encourage those of you who are working in the field of learning and teaching in higher education to contribute to future issues (details on page 55).

We hope you will find something to inspire you in these pages.

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.

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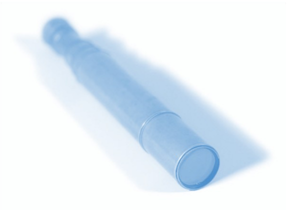

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Epistemological beliefs and intellectual development in the physical sciences

Abstract
Much research has been documented on the stage of students' intellectual and epistemological development during their studies and upon course completion. To a large extent, the literature suggests that promoting students through the intellectual framework is a desirable feat. Indeed, students graduating from university at the more developed stages of intellectual and epistemological sophistication are better equipped to synthesise, evaluate, organise and cross reference knowledge into different domains.

In this review, modes of epistemological beliefs will be discussed as sources of valuable information to departments about the quality and nature of students' perceptions of learning and teaching. The results of recent research in epistemological and intellectual development will also be discussed; this perhaps being a mechanism to inform learning and teaching practices within the physical sciences.

Epistemological and Intellectual Development

Epistemology refers to the justification, nature, sources and evaluation of knowledge[1, 2, 3]. It has been reported that epistemological and cognitive sophistication is positively related to skills such as critical thinking, self regulation[4], ability to communicate ideas and to learn in collaboration[5]. Indeed, physical scientists may be viewed as professional epistemologists in that they use prior knowledge to generate knowledge through explicit and reliable methods. How students construct knowledge during their university years is important for their future careers where the ability to integrate, evaluate and apply scientific knowledge is required.

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The investigation of students' perceptions of learning, teaching and epistemological beliefs in the sciences has been widely researched because of their influences on learning, goal orientation and use of cognitive strategies[6, 7, 8]. This has been a relatively active area of research[8, 9] and can be traced back to the original intellectual and developmental work of William Perry in 1968[10]. His theory offered an unfolding of students' views on development, learning, authority and the nature of knowledge as they progress through their university years. A scheme that conceptualised the development of higher cognitive skills was formed (Table 1), providing a specified hierarchal sequence of human experience from basic duality to identity, commitment and maturation (see also the work by Bhattacharyya[11]). The intermediary stages are typified by dissonance where individuals encounter and recognise imperfections and fallibilities in 'authorities' (e.g. models, textbooks etc).

Perry argued that the most significant intellectual shifts occur during university, when students are confronted with and expected to reconcile multiple authoritative sources. Cognitively, students become active generators of their own knowledge and become socially aware of their commitments and identities.

Perry reported that few students enter university at the basic dualistic stage and in his study; he found that over 70% of students leave university having attained levels of commitment, exemplified by stages 7 and 8. Perry also suggested that individuals may depart from the main line of development by suspending, nullifying or even reversing the process of growth.

Table 1: Perry's scheme of intellectual development as applied to the learning situation

Stage	Description	The learning situation
1: Basic duality	The student views life in polar terms of right v wrong. The correct answers are known to Authority whose role is to mediate them. Knowledge and goodness are to be collected by hard work and obedience.	The student is a passive acceptor of factual, clear cut knowledge that is committed to memory and obtained solely from the lecturer. Exams are viewed entirely from a factual objective perspective.
2: Multiplicity pre-legitimate	Diversity of opinion is evident and the student accounts for this as poorly qualified Authorities. Students may even view this diversity as mere exercises where they are required to obtain the right Answers on their own.	
3: Multiplicity Subordinate	The student begins to accept diversity as legitimate since the limitations of duality are exposed. However, the standards required (e.g. for grading) are vague.	The student may sit in a trough of dissonance where the factual clear cut nature of knowledge, authority and responsibility is unclear. The student appreciates that the dualistic construct may not be absolute, and requires guidance from the lecturer for knowledge, assessment and grading.
4a: Multiplicity correlate or relativism subordinate	The student perceives that diversity of opinion and uncertainty to be legitimate "and raises it to the status of an unstructured epistemological realm of its own" where everyone has the right to their own opinion. This is now set over Authority's realm of right-wrong.	
4b: Multiplicity correlate or relativism subordinate	The student begins to discover contextual relativistic reasoning.	
5: Relativism correlate	The student views all knowledge and values as contextual and relativistic and completely dismisses the dualistic perspective.	Students are active constructors of knowledge and view themselves, peers and lecturers as legitimate sources of knowledge. The student enjoys debating in different contexts and views exams as opportunities to demonstrate skills, creativity and independent thought. Relativistic thinking becomes the norm and can confidently discriminate between facts and opinions.
6: Commitment foreseen	The student appreciates the relativistic world and needs to orientate himself towards some sort of commitment.	
7: Initial commitment	The student constructs an initial Commitment in some area.	
8: Orientation in implications of commitment	Implications of his commitment are evident and the student explores his realm of responsibility.	
9: Developing commitment	Through the initial affirmation of identity, commitment and responsibility, the student views life as an ongoing journey where multiple commitments and responsibilities are required.	

Recently, much emphasis is placed upon how university experiences affect students[12], and Perry's theory has remained the cornerstone and guiding framework of many research studies of student development, throughout their education and onwards throughout their careers.

Because of limitations in the original scheme, other similar theories[13, 14, 15, 16] have since been reported and most are concerned with the development of individuals' beliefs ranging from the stance of black and white absolute thinking to a sophisticated, evolving and rationally evaluated viewpoint of the world.

Literature review

How students approach their physics learning has been reported to be related to their perceptions of knowledge and the nature of physics[17, 18, 19, 20]. For example, May and Etkina[18] have shown that through the use of students' submission of weekly reports, those students who showed higher conceptual gains were more likely to mention more developed epistemological learning activities, such as learning formulae with conceptual understanding with a lesser reliance on authority. Nussbaum, Sinatra and Poliquin[21] have reported that those students classified as evaluatists interacted with knowledge more critically and were better at solving physics problems than those students who were classified as multiplists. Multiplists were less critical of misconceptions and inconsistencies in relation to problems in air and gravity. Richter and Schmid[4] showed that epistemological attitudes and beliefs affect self regulated learning. Hammer[17] also reported that novices tend to solve problems by manipulating formulae where physics knowledge is organised by surface features as opposed to by physics principles.

Another study illustrated that student success in an introductory undergraduate physics course for naïve learners, is dependent upon student's cognitive understanding and on their epistemological beliefs of physics[22]. Their weekly interviews over 12 weeks looked at students developing conceptions of sound and wave motion. Although the sample size reported is small, an in depth analysis revealed that naïve first year physics undergraduates tend to use different models than experts for understanding sound and wave motion. Their interviews elucidated three 'types' of students:

Table 2: Example of an Osgood type questionnaire

It is good to work with other students because listening to their points of view, I can correct my ideas							I prefer not to work with other students because I might pick up some wrong ideas
I think lecturers should avoid teaching material that they know students will find difficult.							Lecturers should aim to provide challenges to students by introducing difficult topics.
All I have to do in science is to memorise what has been taught							Understanding science is the key to scientific study

1. Some students (without prior physics knowledge) believed that scientific knowledge is conceptual knowledge and developed most of their preinstructional conceptions into acceptable scientific conceptions. Their beliefs about physics knowledge enabled them to choose viable study methods where the physics that they learned in lectures was helpful for understanding the real world.
2. Some students (with prior physics knowledge) believed that physics knowledge is mathematical knowledge and did not develop their conceptions well. Their beliefs that physics problems were simply mathematical formulae and the physics they learned in lectures were not relevant to everyday experiences.
3. Some students viewed physics knowledge to be made up conceptual knowledge where the ultimate goal was to understand formulae to solve problems mathematically. However, no effort was placed on appreciating the conceptual content that was involved. They believed that learning in physics was totally unrelated to their everyday experiences because of the complicated words and meanings.

The progression in student thinking showed that conceptions developed from everyday conceptions to unclear scientific conceptions and finally to scientific conceptions. However, this illustrated that the extent of students' previous physics knowledge did not necessarily influence the development of their physics conceptions.

Although set at secondary school level, it has been reported that epistemological sophistication in physics can be a predictor of conceptual understanding in physics[7]. Stathopoulou and Vosniadou[7] explored this relationship and all students who showed a deeper understanding of Newtonian dynamics were students with highly sophisticated beliefs. Interestingly, Liu and Tsai[2] examined differences between science and non-science majors on their epistemological views. Their results indicated that science majors have less sophisticated beliefs in the theory-laden and cultural aspects of science than non-science majors. They account for this by suggesting that science major students might have been longer involved in an epistemic environment that described scientific knowledge as being objective and universal.

In the Swedish context, Domert, Airey, Linder and Kung[23] analysed undergraduate and postgraduate students' epistemological beliefs in learning physics equations. They found that advanced physics students felt the need to understand the underlying physics concepts to be more important than those at the earlier stages of their studies. The authors suggest that physics students at the early stages of their learning should be encouraged to link equations to everyday life.

The study by Sins, Savelsbergh, van Joolingen and van Hout-Wolters[8] explored the relation between students' epistemological understanding of models and modelling and of their cognitive processing (i.e. deep versus surface processing[24, 25]) on a computer based physics task. They found (and expected) a positive correlation between students' level of epistemological understanding and their deep processing. This is similar to the work reported by Ozkal, Tekkaya, Cakiroglu and Sungar[26] in that students who believed that knowledge was tentative appeared to use learning strategies that resulted in deeper processing of information. In addition, Scherr and Hammer[27] argued that the concept of observing students' behaviours *in situ* in small group physics tutorials can be useful for determining student epistemologies. For instance, "A student may frame a physics problem as an opportunity for sense-making or as an occasion for rote use of formulas". They found that verbal and non-verbal displays reinforce each other and provided evidence for certain student behaviours that indicate a support for epistemological framing.

Tsai[28] discussed a constructivist internet-based learning environment for students and reported that more advanced graduate students require opportunities to negotiate ideas, reflect and explore epistemological issues. In addition, students with more internet experiences tended to prefer more features of the constructivist internet-based learning environments than those with less internet experiences. He believed that the internet based learning environment can be perceived as an epistemological tool (as opposed to a cognitive tool) where learners can "develop evaluative standards to judge the merits of information and knowledge, thus exploring some epistemological issues."

What the above studies tend to suggest is that a consideration of epistemological beliefs and attitudes is important in the physical sciences – both for educational practice and research.

Interventions

There is a general consensus in the literature that encouraging students through the intellectual and epistemological framework is a desirable aim of higher education[29, 30]. Indeed, it is known that sophisticated epistemological beliefs exert a positive influence on students learning strategies and learning outcomes[31, 32].

In the chemistry laboratory:

Whilst not explicitly related to epistemological and intellectual development, the research of Kelly and Finlayson[33] has shown that a problem based learning approach in the chemistry laboratory is more conducive to learning and understanding chemistry when compared to a traditional approach. They researched students' attitudes to learning in a problem based laboratory (where the procedure is student generated) as opposed to the traditional expository laboratory. It may be argued that this technique would encourage intellectual growth, as reported by the case of MacKenzie, Johnstone and Brown[34] in the context of medical education. Their results showed that students undertaking the new problem based learning curriculum demonstrated a more critical, self directed approach to learning and argued that the same can be embedded within science curricula.

Scientific argumentation – web and individual text based:

Embedding skills of scientific argumentation[35] within an introductory physics course has been shown to encourage students to develop more scientific criteria in discussions, in addition to increasing success and conceptual understanding of physics problems[21]. The study was conducted on an online web environment (n=88 undergraduates); this being the vehicle for student discussions, in addition to documenting and coding responses for analysis. Both groups completed online questionnaires on the scientific disposition to argue and an epistemic belief survey and were equally divided into groups. The treatment group received additional online skills in scientific argumentation. The intervention was found to have positive effects in terms of the number of thought experiments, alternative views and qualities of scientific arguments. Although students' willingness to engage in argumentation can vary, the authors argue that it is an important part of the socially constructed nature of scientific enquiry.

The work conducted by Mason, Gava and Boldrin[36] with pupils in Italy, investigated two types of instructional texts in light, vision and colour: (1) an ordinary expository text whose function was to give new information and (2) a "refutational text that not only gave new, correct information but also explicitly stated and refuted alternative conceptions by presenting the scientific conceptions as viable alternatives". They found that the refutational text facilitated students understanding of new concepts and situational interest.

Overall, epistemological beliefs and exposure to the criteria for sound scientific argument can affect learning of physics concepts – an increasingly important area since research has reported that students may complete physics courses without a proper conceptual understanding of physics[37].

Historical perspectives of chemistry:

Using written reports and classroom discussions, Niaz[38] has shown that when students are given the opportunity to reflect and debate various chemistry topics (such as the various models of the atom), understandings of the nature of science can be enhanced (see also the exploratory work of Ibrahim, Buffler and Luben[20]. Niaz also concluded that the interaction among participants facilitated the progressive transitions in students' understandings of the nature of science.

Course type and environment:

Tolhurst[39] conducted a study to examine how epistemological beliefs may be affected by the implementation of a new course structure. It was found that students were more actively engaged in their learning and positive changes in epistemological beliefs were generated. In addition, students with sophisticated epistemological beliefs attained better results in the end of year examination. More recently, other work by Baily and Finkelstein[40, 41] has demonstrated how students evolve in their thinking as they moved from classical physics to quantum physics. It was found that student perspectives change when making the transition between classical physics (realism, where all physical quantities within that system can be specified simultaneously) and quantum mechanics.

Summary

In order to inform learning and teaching practices, departments may wish to document and analyse students' epistemological and intellectual development during a degree course[42] (or before and after an intervention). In turn, the results of such research might further influence the way departments support learning and teaching, and in particular for future student cohorts. Much of the research described above shows that when it comes to learning physical science concepts, student epistemologies matter. In designing effective learning environments, researchers suggest that it is important to develop and evaluate curricula that will facilitate the development of sophisticated epistemological beliefs[7].

Appendix – Questionnaires

As the Perry scheme is relatively complicated, various simplifications[15, 42, 43] have been offered, mainly as a means of simplifying measurement and presentation. Various attempts in the literature have been made to convert the epistemological framework into a questionnaire, some of which are listed below:

(1) Example of an Osgood type questionnaire (Table 2)
(2) Evaluation of Teaching, Higher Education Academy Physical Sciences Practice Guide[42]
(3) Views on the nature of science instrument[44]
(4) Student submission of weekly reports[18]
(5) Views About Science Survey (VASS)[45]

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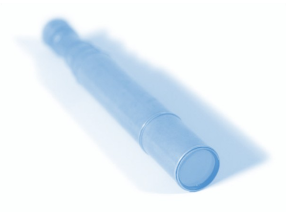

A legacy for chemistry education

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At A-level and degree level the focus is on increasing the numbers of students studying chemistry and the chemical sciences to educate the next generation of science-based professionals.

Abstract
The Royal Society of Chemistry (RSC) has a longstanding reputation for providing innovative and up to date support for chemical science education – from primary, through to higher education and beyond. The RSC is continually developing easily accessible resources and events to help meet the needs of changing curricula and the skills required by employers.

At A-level and degree level the focus is on increasing the numbers of students studying chemistry and the chemical sciences in order to educate the next generation of science-based professionals. The Chemistry for our Future (CFOF) programme was established with the aim of ensuring a strong and sustainable future for chemical sciences in higher education by increasing the aspirations of students, promoting the chemical sciences at all levels and improving the school to university transition.

The background
Chemistry for our Future was funded by the Higher Education Funding Council for England (HEFCE) and managed by the RSC. The initiative began on 1st September 2006 with initial funding of £3.6m. A further £1.65m was secured to extend *CFOF* until July 2009. The programme involved over 35 separate projects and 30 higher education institutions, covering four main areas:

- *Chemistry: The Next Generation* (*CTNG*)
- Teacher and academic fellowship scheme
- Higher education curriculum development
- Widening access to university laboratory facilities

Two cross cutting themes addressed the provision of career information and the sharing of good practice.

Future generations
Chemistry: The Next Generation (*CTNG*) was an outreach project that aimed to raise aspirations and engage with students from backgrounds that do not traditionally participate in higher education. The project operated in six English regions – the South East, London, North East, Yorkshire and Humber, East Midlands and North West – and its strength lay in the range of collaborative events that enhanced and enriched the curriculum and met the needs of local schools and colleges. The programme was managed centrally by the RSC and was run ‘on the ground’ by Regional Coordinators who worked closely with the higher education institutions in their region as well as other outreach providers. Over 60,000 students have been involved in outreach events since September 2006.

These events have provided a new cohort of students with first-hand experience of the chemical sciences in action, including activities such as *Murder in the lab* – where the students used forensic techniques to investigate a ‘murder’; *Aspirin, the wonder drug; Make your own electrochromic polymer; Renewable energy from sunlight to electricity* and *Building molecules.* For information on these and other activities visit the RSC website at www.rsc.org/Education/CFOF

Bridging the gap
For many students the transition from school to university is not always smooth and *CFOF* has tackled this through a range of new initiatives, including chemistry ‘boot camps’ and on-line maths resources, aimed at boosting students’ confidence, learning and practical mathematical skills.

Nine secondary school teachers have also spent up to two years working in their local university, to work on a range of enrichment projects as part of the teacher and academic fellowship scheme. The Teacher Fellows undertook work to:

- improve understanding in universities of A-level chemistry and GCSE science courses, current practices in schools and colleges, and the capabilities of incoming undergraduates;
- raise awareness amongst teachers, students, parents and guardians of what it is like to study chemistry at university, the benefits of higher education and the career options available to chemical science graduates; and
- develop sustainable links between universities and schools and colleges.

One teacher fellow described what the scheme provided for them; 'When I return to school I am in no doubt it will be as a more effective and enthusiastic teacher. This really is a great job'.

The teachers have worked at the universities of Sheffield, Nottingham, Birmingham, Warwick, Bath, Leeds, Newcastle, Northumbria and University College London on a variety of projects. These have included developing new curriculum-based outreach activities, undertaking evaluations of first year teaching and developing an Interactive Lab Primer (ILP), which is a visual guide to common laboratory techniques (www.rsc-teacher-fellows.net/index.htm). The aim of the ILP is to address the diverse range of experience and practical skills that students bring with them to university by providing extra support in developing practical techniques, familiarisation with new pieces of equipment and information on working safely.

Ten university-based pilot projects have also been developed, focussing on improving the school-to-university transition. Together, they address the key areas of maths and practical skills, new teaching materials and student support schemes: www.rsc.org/Education/CFOF

The projects have concentrated on a wide range of activities to help students overcome the sometimes difficult transition from school to university. This has included developing on-line resources to cover the essential mathematical principles that chemists need to apply and also reviewing how maths is taught to undergraduates. Practical skills have also been honed through pre-induction courses and knowledge gaps have been addressed by using short on-line video clips focused on 'bite sized' learning objectives. These projects have achieved much in a short period of time and hopefully they will continue to evolve and provide further benefit for students and those teaching and supporting them.

Developing HE curricula

Chemistry for our Future provided a unique and timely opportunity to review existing chemical science degree courses to ensure that courses appeal to prospective students from all backgrounds and deliver the skills required by employers in the chemical, pharmaceutical and other industries.

The higher education curriculum development strand of *CFOF* was grouped into the following themes:

- developing Context- and Problem-Based Learning;
- developing an open learning framework; and addressing the challenges of the Bologna process.

Chemistry for all - alternative approaches to chemistry curricula

The focus of this project was to provide a data set for evaluating the effectiveness of Context-Based Learning (CBL) and Problem-Based Learning (PBL) in chemistry curricula. The project was carried out by the universities of Leicester, Hull, Nottingham Trent and Plymouth and had the following aims:

- To implement existing CBL/PBL materials into undergraduate chemistry courses at four English universities.
- To measure the effects of these alternative approaches with different student groups (*e.g.* full time, part time, foundation degree students and distance learners) in terms of student performance, student satisfaction and engagement, staff perception and resource implications.
- To investigate the transferability of existing CBL/PBL materials to institutions other than those where they were initially developed.
- To survey materials being used in other institutions.
- To share good practice, ideas, materials and innovations and provide rational cross-discipline planning in collaboration with the parallel HEFCE funded, Institute of Physics managed project, *Stimulating Physics*.
- To identify new areas for future development.
- To develop new resources tailored for the delivery of CBL/PBL approaches.

Mastering Bologna

With 2010 fast approaching, the Bologna process is a pressing issue for HE. In chemistry and the chemical sciences there are areas of the process that will potentially have a huge effect on both students and HEIs. The aim of this project was to gather data and opinion on the readiness of the UK chemistry HE sector to succeed after the introduction of the European Higher Education Area (EHEA). The Bologna Agreement defines a route to a pan-European structure for higher education provision, which in practice could mean three year BSc degrees followed by two year Masters and then three year PhDs.

The *Mastering Bologna* report was launched in December 2008 and the findings and recommendations show there is still a lot of work to be done before the Bologna Agreement comes into effect in 2010.

The Bologna Agreement will introduce three main cycles of higher education qualifications; a three year Bachelors followed by a two year Masters and a three year PhD. This model will be adopted by universities across Europe to allow for greater international mobility between member states (EU and non-EU) for study and employment through mutual recognition of HE qualifications.

While many countries in the EU already fit this model, the UK falls short at the second cycle where the common duration for a Masters is only one year. The chemistry HE sector faces a further obstacle with the highly popular integrated Masters qualification – *e.g.* MSci and MChem, which removes the second cycle altogether.

The report findings show that it is unlikely the integrated four year Masters will be acknowledged internationally as equivalent to a combined first and second cycle qualification in the EHEA[1]. With approximately 40% of UK chemistry graduates qualifying with this degree, this poses a huge threat to UK graduates competing for employment, both domestically and internationally. Should the MChem and MSci degrees lose their reputation for providing graduates with good employment prospects their popularity with overseas students will also decline. This ultimately will have negative consequences for the sustainability of a number of UK chemistry departments[1].

While many of the surveyed universities favoured a move to the Bologna system, no consensus was found for a general model. Furthermore, the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of 11 UK Chemistry departments showed that implementation of a five year model to Masters graduation would require substantial new funding, both from students and institutions.

The report recommends:

- two academic years of Masters level education should be made widely available in the UK although the current four academic year integrated Masters degrees are to remain for the foreseeable future;
- the nomenclature of UK science degree programmes needs to be rationalised to avoid confusion outside the UK;
- higher education institutions should continue to strengthen links with industry in the direct provision of student learning opportunities;
- HEFCE and the Research Councils need to agree financial responsibilities for Masters degrees and make sustainable new provision for Masters level education; and
- HEFCE and the Research Councils need to consider new funding for scholarships for UK students undertaking Masters courses.

The full report is available on the RSC website at: http://www.rsc.org/images/MasterBologna_tcm18-159351.pdf

Smarter use of laboratories
In recent years chemistry, amongst other science subjects, has suffered from a reduction in the number of applications for degree courses. Whilst the latest UCAS data shows that acceptances to chemistry are at a 10 year high there is clearly much more work that needs to be done to sustain this increase in applications. This can be tackled, in part, by improving young peoples' perception of science and by promoting and facilitating sound scientific understanding and training. Research shows that there is a need to make science more engaging in the classroom through practical experiments. Hands-on work helps to make science compelling for young people. However, a lack of good laboratory facilities and equipment in many schools and colleges makes this difficult.

Chemistry for our Future has worked with the Bristol ChemLabs CETL and the University of Sheffield to explore ways of making better use of university laboratories to benefit students in secondary schools and colleges. These projects gave school and college students a taste of what it is like to study chemistry at university. Activities included introductory sessions for Year 11 students, GCSE revision workshops and a suite of curriculum based experiments.

As one student says; 'The day gave me an insight into working in a laboratory and has inspired me to choose a course at university with a biology and chemistry base'.

These initiatives support science teaching for Year 5 to Year 12 students and their teachers, by providing access to good quality practical facilities. This gives students the opportunity to do experiments they may not be able to do in their classroom and encourages them to consider continuing to study science. By giving the students the chance to use the schools laboratories on more than one occasion, they experience a sustained engagement with higher education rather than a more limited 'one-off hit'.

As one student says; 'The day gave me an insight into working in a laboratory and has inspired me to choose a course at university with a biology and chemistry base'.

The teachers also enthused about the facilities; 'The students were unanimous in their responses about their experience. They all said how much they had enjoyed the day. They felt they learnt some good and relevant chemistry and also felt that the practical exercise was very worthwhile. They have even asked if they can go again next term'.

Another initiative promoting laboratory techniques is *Spectroscopy in a Suitcase* (SIAS), which brings the laboratory to schools and colleges. Postgraduate students take cutting-edge spectroscopy equipment into classrooms across England to give students practical experience of the theoretical techniques they are learning about.

Spectroscopy resource packs have been designed to compliment the SIAS workshops but are equally valuable as stand alone resources. Each pack contains a range of activities on infrared spectroscopy, UV-visible spectroscopy and mass spectrometry. In one instance, students work through a murder investigation and have to discover the cause of death with the aid of infrared spectroscopy. Other activities include screening for aspirin overdose and studying food dyes using UV. By relating the techniques to real investigative activities students can see for themselves why spectroscopy is such a vital tool in analysis.

Chemistry for our Future has also developed free online resources to support spectroscopy teaching in schools and colleges (www.rsc.org/Education/CFOF). *SpectraSchool* was re-launched in January 2009 at the Association of Science Education (ASE) conference and provides real, interactive spectra of IR, NMR, UV-Vis and MS for a large library of compounds. Students (and teachers) can study and compare spectra by zooming and overlaying compounds and there is also the opportunity to watch video clips illustrating the practical aspects of the techniques. These extra resources will really help maximise the impact throughout the country.

Chemistry for our Future worked closely with schools, colleges, industry and HE around the country promoting chemical sciences as a stimulating and profitable career.

Other themes

There are many exciting career opportunities available with a chemical science qualification and *CFOF* has worked to provide students with the most up to date information. New resources were developed in collaboration with chemical science employers and events were run that gave students and careers advisers the chance to meet real scientists and find out what it's like to work in a particular field.

Chemistry for our Future worked closely with schools, colleges, industry and HE around the country promoting chemical sciences as a stimulating and profitable career. This led to a wide range of activities targeting students from primary school level to A-level, and with a particular emphasis on widening participation.

A series of careers fairs in Birmingham, Norwich and Paignton was developed as part of the programme to give students the chance to meet employers, listen to presentations and take part in hands-on activities. Two careers conferences were also held to inform teachers and career advisors of the career opportunities available in the chemical sciences, through a series of workshops, presentations and exhibitions.

A major aspect of *CFOF* has been the collection of baseline information and evaluation of activities. One specific project in this area has been research to examine the fit between the supply and demand of chemical science graduates in the UK. The work was undertaken by the Warwick Institute for Employment Research, looking at the employment perceptions, attitudes and experiences of chemical science students and graduates at different stages of their career development. General graduate and specialist chemical science employers were asked questions about their experiences of recruiting chemical science graduates, the types of jobs they do within their organisation and their perception of the skills chemical science graduates possess.

The study provided a wealth of information with some of the key findings listed below.

- Students reported a high degree of satisfaction with their chemical science courses and with the HE experience in general.
- A third of final year students said that they broadly knew what they wanted to do and how to do it, with 45% seeking careers advice in the previous two years.
- Work that was challenging and interesting was the most important thing that students looked for when considering suitable jobs.
- General graduate employers stated that they were unlikely to favour MChem graduates over BSc graduates and were more interested in transferable skills. However, specialist chemical science employers did distinguish between the two, with higher degrees particularly sought after for research or academic positions.
- The majority of chemical science employers said that they had no problems filling vacancies and they are satisfied with the number of applications.
- Employers felt that skills such as physical chemistry, physical organic chemistry, analytical science and the ability to work on large scale research projects were in short supply.
- Written and spoken communication skills and business awareness were the most common transferable skills that employers felt chemical science graduates lacked.
- Students felt that more could be done to provide them with information about the kinds of careers available and were critical of information they received from employers and professional bodies, stating that it was not detailed enough.
- Employers expressed the concern that chemical science graduates are not aware of the range of options available to them and as a result were less likely to consider areas with good opportunities such as manufacturing and technical sales.

A short digest and the full version of the report are available at www.rsc.org/Education/CFOF.

The legacy
Chemistry for our Future has established many successful activities that have scope for further development to continue to have a major influence on the experience of students in schools, colleges and HEIs. The main legacy of the programme has been establishing successful working partnerships with a range of stakeholders, including students, school teachers, university lecturers, industry and other professional bodies. Outreach activities such as *Spectroscopy in a Suitcase* which are delivered in the classroom will be extended and continue to develop, and the RSC is looking at sustainable ways of continuing the work of the network of regional coordinators.

Several major strands will provide a lasting legacy from the project:

- Universities that have benefited from teacher fellows have started to restructure their degree programmes to better meet the needs of future students.
- New tools have been developed to support students as they settle into university life, these will be rolled out in more universities.
- Networks of HEI staff and teachers with an interest in developing teaching and learning have been established.
- The profile of widening participation has been raised in the chemistry community.
- Future students will benefit from the newly refurbished school laboratory facilities at the University of Sheffield.
- SpectraSchool, a library of spectral data, interactive tools and spectroscopic teaching resources, will continue to be developed and promoted to students and teachers.
- A series of new CBL/PBL resources that are available 'off the shelf' have been developed.
- A better understanding of issues surrounding the Bologna process has emerged, which the RSC will take forward with funding agencies and other professional bodies.
- A framework for an effective national outreach scheme has been established.

The future
The Higher Education Funding Council for England (HEFCE) announced earlier in the year that the University of Birmingham will host the national Higher Education Science Technology Engineering and Maths (STEM) programme for a period of three years from August 2009. The integrated STEM programme will have a potential budget of £20m and will build on the successes of the four current HEFCE funded STEM demand-raising projects; *Chemistry for our Future, Stimulating Physics*, *More Maths Grads* and the *London Engineering Project*. The aim of the programme is to deliver a sustained increase in STEM graduates, meeting the needs of employers and satisfying the demand for higher-level skills in STEM subjects.

The main legacy of the programme has been establishing successful working partnerships with a range of stakeholders, including students, school teachers, university lecturers, industry and other professional bodies.

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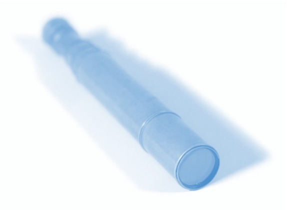

Public engagement with a twist

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The University of Edinburgh has been active in Public Engagement with Science since the 1990s and provides training in Science Communication for post-graduate students and post-doctoral researchers, through its 'Transkills' (transferable skills) programme.

Abstract
An increasing number of post-graduate students and post-doctoral researchers in the College of Science and Engineering at the University of Edinburgh do not have English as their first language. Indeed some researchers have barely acquired the minimum standard of English required by the College. This hinders their own development as scientists and engineers and also has implications for undergraduate tutoring and laboratory demonstrating in their science and engineering disciplines. To address this issue, an English Language Skills course was developed in collaboration with the Institute for Applied Language Studies (University of Edinburgh). The course uses the techniques and activities of science communication training for Public Engagement in sessions dedicated to learning English. Part of the rationale was that students would find comfort and confidence in their scientific knowledge, and would therefore feel empowered to speak out and improve their English skills. This case study outlines the development and implementation of the course, includes feedback from the participants and observations on the course.

Background
The University of Edinburgh has been active in Public Engagement with Science since the 1990s and provides training in Science Communication for post-graduate students and post-doctoral researchers, through its 'Transkills' (transferable skills) programme.[1] One such training programme, 'Science Communication in Action' (now 'Research Communication in Action') offers a course which combines both generic and subject-specific science communication training, together with opportunities to gain experience in science communication in 'real' settings; for example in primary and secondary schools and at the Edinburgh International Science Festival. Elizabeth Stevenson from the School of Chemistry delivers both generic and chemistry-based training for 'Science Communication in Action'.

An increasing number of students enrolling for the course do not have English as a first language. Indeed, some students misunderstood the purpose of the course and assumed it was an English Language Skills Course as opposed to training for Public Engagement with Science.

Within the College of Science and Engineering there are growing numbers of international post-graduate students who have limited English language skills. Post-graduate students are encouraged to participate in undergraduate teaching activities such as laboratory demonstrating and delivery of tutorials, as part of their overall training. However, the limited English language skills can prevent some students from being involved in teaching activities, present difficulties for them integrating into their research groups and can limit their contributions at research group meetings. A quick survey of students with limited English language skills indicated that students would welcome additional language skills training.

The science communication training provided by 'Science Communication in Action' involves participation in different activities; for example role play, delivering and following instructions, explanation of science research in everyday language without the use of jargon, questioning and listening. The teaching of English as a second language now also tends to be activity based or task based [2]; for example map-reading, delivering and following instructions, questioning and listening.

Thus the 'experiment' was to explore the use of science communication training, together with science and engineering focused activities, to develop an English language skills course specifically for those students for whom English is not their first language. The rationale was that participants would be comfortable with the subject matter of the activity and thus feel empowered to speak out and improve their English language skills, with the additional bonus of developing skills and experience in Public Engagement.

Development
This concept was enthusiastically received by the Institute for Applied Language Studies at the University of Edinburgh (Mr Eric Glendinning and Dr Tony Lynch) and by the Coordinator of 'Science Communication in Action' (Dr Briony Curtis), who assisted in the development of a pilot study. Activities were designed to generate real communication, as opposed to mere language practice, so some form of underlying 'gap' was built into each activity. Such gaps have been summarised by Prabhu [3] in terms of information, opinion and reasoning. In an *information gap* task, the learners might each be given one of two different versions of a text, which they have to read and understand, before talking to a partner who has seen the other version, and they have to reconcile the two. In tasks involving an *opinion gap* everyone is given a text on a controversial topic, reads it and then debates the issue in pairs before coming together for a wider exchange of views. In a *reasoning gap* task, the learners are given enough information to be able to discuss a solution to a problem, but instead of being asked simply to choose and argue for a set of alternative solutions, they have to come up with a solution themselves.

After an initial pilot within the School of Chemistry, a format for a language skills course consisting of one initial half-day session followed by a one-hour session per week for six weeks was developed. Post-graduate students and post-doctoral researchers from the College of Science and Engineering were invited to attend.

Experimental - what we did
Week 1 (half-day session in three segments)
Segment 1
This consisted of a laboratory-based exercise using a simple science demonstration which was divided into two parts. The demonstration involved testing an acidic solution (vinegar) and a basic solution (sodium hydroxide) with Universal Indicator (model demonstration 1), followed by testing of 'Dry-Ice' [4] (solid carbon dioxide) together with an exploration of the property of sublimation (model demonstration 2). Key words were written on the white board as 'aide memoires' for the demonstration.

- model demonstration 1 by Elizabeth Stevenson (ES) to students (A- H)
- student demonstrations in parallel pairs: A- H (Instructors) to I- P ('Pupils')
- students I- P were asked to assume the role of 10 year olds.

Language feedback by Tony Lynch (TL)

- model demonstration 2 (by ES) to students I- P
- student demonstrations in parallel pairs: I- P (Instructors) to A- H ('Pupils')
- students A- H were asked to assume the role of interested parents.

Language feedback by TL.
The activity described above is a science communication training activity used for native speakers to test their ability to give accurate instructions in a logical order without using scientific jargon and to answer questions in everyday language.

Segment 2
Jigsaw text: each student was given a different printed sentence from a paragraph of text which they memorised. Then they worked with the other students to sequence and finally dictate the paragraph. The paragraph we used was extracted from the School of Chemistry Safety Handbook from the Fire Regulations and Information. Language feedback (by TL)

Segment 3
Self-presentation on being a research student i.e. brief description of career to date.
Preparation of self-presentation by students
In pairs: self-presentations (A to B, then B to A)
Plenary: each student presented information on the partner (B about A) to whole group.
This is an exercise used in science communication training to help develop a) listening skills and b) the ability to describe one's area of research in everyday language.
Summary/Roundup on language (by TL)

Week 2: Scientific questions
Each student wrote their own question and feedback was given on the language. The topics could be drawn from any area of science. In groups of 3 or 4, students related their questions and decided on the order in which they wished to discuss them. Questions were discussed for 15 minutes while being monitored. Language feedback was given. New groups were formed and they followed the same procedure, discussing the same questions but with different partners. Further feedback was given at the end of the session.

Week 3: Text to Speech
This was a two stage activity: stage 1 is a short piece of written homework; stage 2 took place in the class.
Stage 1
Students wrote a short text summarising one of the following topics:

- a controversy in their field of study
- an important area or a recent development in their field of study which they feel is not well known to the general public, but which they believe should be.

In class, working in pairs, they explained to each other orally the issue they had written about and answered any questions from their partner. The exercise was repeated with different partners.

Week 4: Jigsaw reading/speaking (as described earlier and using a science based text)

Week 5: Science writing in the media
This exercise comprised a discussion related to reporting of a scientific finding: a) to the public in a popular newspaper and b) to fellow scientists via an academic journal. This exercise is used in science communication training to explore different versions of the same story relayed for different audiences.

Weeks 6 and 7: Short presentation on own area of research for a non-specialist audience followed by questions.
This exercise is an integral section of 'Science Communication in Action' and allows participants to explore their choice of words and the level of explanation necessary

for a non-specialist audience to engage with the science. Although the speaking activities varied in their use of oral and written information and students' own experiences, their common purpose was to create a natural platform for the students to practise communicating in English. The students work first in pairs (or trios, if there is an odd number of students), before coming together as a group for the post-task phase, in which they receive feedback from the language tutor (Tony Lynch or John Palfrey).

In contrast to the traditional language teaching procedure of 'presentation, practice, production' (PPP), in the task-based approach the language learners work through three phases, which have been characterised as *rehearsal*, *performance* and *debriefing* [5]. In the Pre-Task phase, they prepare for or rehearse the communication activity. During the Task phase they carry out the activity, typically in pairs or small groups; having completed the activity with one partner, they may move on to a new partner, since recycling of language activity has been shown to improve linguistic accuracy [6]. In the Post-Task phase or debriefing, the whole class come together to receive feedback on their performance; this may be based on observations by the teacher, perceptions from the learners, or both in combination.

While the pairs are carrying out their communication task, the tutor moves around the room, monitoring what they are saying and how they are saying it, and noting down points that they think should be brought to the group's attention after the task.

While the pairs are carrying out their communication task, the tutor moves around the room, monitoring what they are saying and how they are saying it, and noting down points that they think should be brought to the group's attention after the task. One method of structuring the linguistic feedback is to categorise the tutor's comments under headings such as Vocabulary, Grammar, Stress (emphasis on a particular syllable) and Pronunciation. Issues of vocabulary and grammar are relatively straightforward; stress and pronunciation refer to different aspects of the way a student pronounces.

When the students have completed their speaking task, the tutor calls the class together and takes them through the points they have observed and noted down, grouping them by error types. Given that an additional aim of the course is to help the students communicate with non-specialists or non-scientists, it is also important that the tutor draws their attention to 'in-group' use of scientific terms and abbreviations, such as 'DNA sequence polymorphism data' and 'NMR' (mistaken for enema by the tutor!), which can be taken for granted when talking to fellow research students but which would not be understood by the public. Particular attention is also given to the specific use in science of everyday words such as 'element', 'basic', 'natural', etc.

Having worked through their points, the tutor asks the students to raise any other points themselves that occurred as they were engaged in the task, such as when they were unsure which of two words to use in context, or when they noticed that their partner seemed to be having difficulty understanding an expression they had used, and which they now want to check with the tutor. The airing of such doubts provides the opportunity for learners to fix in place or correct language points about which they would otherwise remain unsure, and the creation of this space for their discussion in the feedback phase is a valuable part of the tutor's role.

Observations

- The laboratory session proved to be an excellent ice-breaker and fostered a comfortable atmosphere within the group.
- Participants appreciated the opportunity to be 'corrected' in their use of language.
- Participants found it relatively easy (compared to native speakers on Science Communication in Action courses) to describe their research in everyday language. The participant group consisted of students from chemistry, biology, maths, and informatics so it was appropriate that students used accessible language, not discipline-specific jargon, to communicate with each other. They were also able to gauge the level at which to engage their 'audience'.
- One group had some feedback for the Safety Committee in the School of Chemistry regarding the sentence order of the Fire Regulations and Information.
- In addition to language skills, students also expressed an interest for clarification of the cultural norms within a British academic institution.
- The biggest obstacle we faced was timetabling a slot when the majority of students were able to attend regularly.
- Feedback was very positive and students particularly liked the opportunity to deliver a short presentation on their research.
- Several students volunteered to assist in facilitating science workshops at the University of Edinburgh contribution to the Edinburgh International Science Festival (EISF)[7].

Quotes from students

"I've really decided to learn English and the course was really good help on my way. I liked the way how we were encouraged to discuss topics that interest us. People were eager to speak in English and tell their opinions - at least I was. :) "

"The way we got feedback was cool: we could first discuss freely, without interruption, and then came the corrections. I like the lists of pronunciation, stress, vocabulary and grammar - that's more or less the way how I study English by myself. I think the points were really helpful - after every lesson I used some time to go through the difficult words mentioned in the lesson."

"I feel I've learned quite a lot! And about homeworks: it was good that we had some of them but not too often. I'm usually a bit critical of everything but now I don't have anything negative to say."

"Thanks a lot for your super English lessons. It was pleasure for me to be involved in your unique course. Your original approach to tuition is sure to help me in my further studying. Would you kindly inform me if you propose resuming such course."

Summary

Participation in EISF workshops was a useful experience for language learning because of the repetition and recycling [6] in English language speaking during the facilitation of the workshops. The majority of participants in science festival workshops are young children, aged ~ 8-12, so clarity of instruction and simple language are essential.

The classes provided a useful two-way engagement experience between researchers of different disciplines and between the researchers and the language tutors.

The class proved popular with the participants and the tutors. However it was initially over-subscribed and some researchers were unable to reserve a place. Therefore we intend to facilitate parallel sessions with the assistance of Public Engagement practitioners from the School of Biological Sciences. This will provide a larger data set for feedback and analysis.

As a consequence of the increase in multidisciplinary research in science and engineering it is increasingly important that scientists, engineers and mathematicians are able to communicate effectively to specialists in disciplines other than their own. Therefore the skills/qualities required for public engagement, i.e. accurate communication of concepts at a level appropriate for the audience, are directly relevant to research.

Acknowledgements

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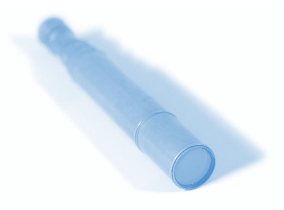

Impacts of assessment in problem-based learning: A case study from chemistry

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Abstract

The use of problem-based learning (PBL) within undergraduate chemistry courses is increasing in popularity. Despite several previous reports describing the impacts of PBL in terms of students' motivation and interest in chemistry, evaluations of its impact with respect to student learning are virtually absent. Here, an evaluation of PBL case studies in chemistry is made by consideration of assessment performance data over a six year period. The performance data are considered at different stages of the undergraduate courses and are compared against related data from laboratory work and closed-book examinations. These performance data are complemented by student feedback. The analysis reveals that, regardless of level, students find PBL case studies enjoyable and motivating. In contrast, performance in assessed work is found to depend strongly on assessment criteria. Students perform comparably with other modes of assessment when the PBL case study assessment criteria are familiar to them. In contrast, when the assessment criteria demand wider consideration of PBL outcomes, typical of those appropriate for the latter stages of degree courses, lack of familiarity with such criteria appears to result in lower performance in assessments, despite careful counselling from the tutor.

Problem-based learning (PBL)

PBL is an approach to teaching and learning that has received increasing attention since it was first described formally in the early 1980s (Barrows and Tamblyn, 1980). The underlying philosophy of PBL is that students advance their knowledge and understanding of a topic by tackling problems related to it. In all cases, the problems cannot simply be solved by application of a series of known algorithms or by reference to a previous or related example. The problems are always placed in an applied context to provide relevance and they require students to work as part of a team towards a common goal. Since the specific problems/contexts are designed in such a way as to be unfamiliar to the students, the tasks are necessarily 'problem-based'. This is different from traditional problem-solving workshops or tutorials where individual students may tackle themed activities as either problems or exercises depending on their experience at the time. There is a growing database of literature describing the use of PBL in HE, though the majority of these focus on descriptions of the principles of PBL and 'best practice' in terms of PBL implementation (Duch et al., 2001; Savin-Baden and Major, 2004).

The underlying philosophy of PBL is that students advance their knowledge and understanding of a topic by tackling problems related to it. In all cases, the problems cannot simply be solved by application of a series of known algorithms or by reference to a previous or related example.

PBL in Chemistry

There are still relatively few reports of specific illustrations of PBL in chemistry. Most examples involve the use of case studies (e.g. Belt et al., 2002; Grant et al., 2004; Heaton et al., 2006; Potter and Overton, 2006; Belt and Overton, 2007) and laboratory work (McGarvey, 2004; McDonnell et al., 2007; Kelly and Finlayson, 2007). A number of years ago, colleagues and I developed a series of PBL case studies suitable for all stages of the undergraduate curriculum (Belt and Phipps, 1998; Belt et al., 1999, 2002, 2005; Summerfield et al., 2003; Belt and Overton, 2007). The case studies were written around a series of applied chemical themes including environmental, industrial and pharmaceutical chemistry. Students routinely described the '*real world aspects*', '*opportunity to put theory into practice*', '*working with others*' and '*getting my own opinions across*' as key features of the case study approach and they welcomed the opportunity to develop professional skills alongside subject-specific skills. The popularity of the PBL case study approach prompted us to write further case study material for areas of core chemistry and these too proved popular with students (Belt et al., 2005). Obtaining positive feedback of this type is, of course, gratifying from a developers point-of-view, and reporting such positive comments likely provides some encouragement for others to consider adopting PBL in their own teaching. Indeed, requests for copies of case study material continue to be received from UK-based chemistry teachers and from lecturers overseas. However, despite the clear value of such feedback, it offers little in terms of providing evidence of student learning or, more prosaically, whether problem-based case studies offer a more (or at least as) effective teaching style compared to other approaches.

Research into the effectiveness of PBL has been reported previously, although the majority of detailed investigations have been in medicine (Gijbers et al., 2005).

Using the perceptions of students as the principal body of evidence for the effectiveness of PBL in medicine, Mackenzie et al. (2003) showed that the PBL approach encourages a more critical and self-directed approach to learning, and that these features would probably be of benefit to science students. Other reviewers have considered the effectiveness of PBL in terms of impacts on student attitude and/or

> *...they particularly appreciate the opportunities that case studies give them to advance their skills, commonly citing group work, time management and presentation skills as those areas of greatest significance for them.*

performance (Albanese and Mitchell, 1993; Berkson, 1993; Vernon and Blake, 1993; Colliver, 2000). The outcomes of these analyses are mixed, with somewhat contradictory evidence for improvements over traditional methods. However, Dochy et al. (2003) have reported positive effects of PBL on students' abilities in knowledge application at the expense of their knowledge base, while Gijbers et al. (2005) present further evidence that PBL is beneficial in terms of promoting the understanding of principles that link concepts.

Reports of PBL in HE chemistry teaching have focussed largely on the rationale for its introduction, descriptions of the specific teaching activities and various logistical issues. In contrast, analysis of the effectiveness of PBL in chemistry teaching has been largely confined to analyses of student feedback data. Students consistently describe the PBL approach as enjoyable and they particularly like studying chemistry in context. In addition, they describe how PBL provides (a) an opportunity for developing key skills (Belt et al., 2002; Belt and Overton, 2007; Heaton et al., 2006); (b) a way of developing confidence with new disciplines or scenarios (Potter and Overton, 2006); (c) a greater appreciation and awareness of the chemical industry (Grant et al., 2004). In the laboratory, students usually find the PBL approach motivating although sometimes frustrating and demanding in the first instance (Ram, 1999; McGarvey, 2004; Kelly and Finlayson, 2007). Perceptions improve, however, with greater experience, and McDonnell et al. (2007) have noted enhanced student learning and better preparation for subsequent project work through PBL laboratory work.

The purpose of this paper is to provide some assessment performance data for students who have completed PBL case studies at the University of Plymouth, with the aim of providing some insights into the effectiveness of this form of PBL on student learning. This paper includes:

i. a presentation of PBL coursework marks for (up to) 6 consecutive years of study (2001-2007);
ii. an analysis of student performance for PBL coursework at different stages of the undergraduate curriculum;
iii. a comparison of student performance in PBL coursework against other (related) coursework and closed book examinations;
iv. A summary of student feedback data.

Using PBL case studies at the University of Plymouth

Stage 2 BSc (Hons) Analytical/Applied Chemistry

Background

Three case studies have been used with Stage 2 Analytical/ Applied Chemistry students since 2001-02. *The Titan Project* is a case study that requires students to research two different manufacturing process for the industrial scale production of TiO_2 and, having considered a range of factors (chemical, economic, environmental, neighbouring industries, etc), make proposals for future development. A second case study, *New Drugs for Old*, involves devising short- and long-term investigations of a potentially new analgesic drug isolated from a natural source, determination of the structures of a series of extracted chemicals using spectroscopic data and physical properties, and proposal of a method of making the most active compound based on some suggested synthetic procedures, economics and scale-up considerations. A third case study, *Tales of the Riverbank*, requires students to consider some basic principles of analytical measurements within the applied context of pollutant species within a river system, together with selection and evaluation of appropriate methodology. These three case studies are described in more detail elsewhere (Belt and Overton, 2007).

Assessment criteria

For each of the three case studies, student groups are assessed through a combination of oral presentations and reports. The assessment criteria, which are the same in each case, focus on the accuracy of solutions to the various problems given the data which is available, together with clarity of presentation. The type of information that students work with ranges from datasets that they will be familiar with (e.g analytical and spectroscopic data) to cases where they have to make 'best-guess' estimates to parameters whose strict correct values are unknown. These too can be wide ranging and can include having to estimate scale-up costs in

Table 1: Summary of Stage 2 student performance data in case studies, laboratory reports and examinations for 2001-2007 (x: No exams taken). Overall module assessment weightings: Case Study: 12.5%; Laboratory Reports: 37.5%; Exam: 50%.

Year	Case Study (%)	Laboratory reports (%)	Exam (%)
2001-2002	73.3 ± 6.9 (n=31)	66.2 ± 10.5 (n=44)	x
2002-2003	67.2 ± 9.6 (n=23)	65.3 ± 9.4 (n=23)	x
2003-2004	62.5 ± 3.5 (n=17)	56.3 ± 11.4 (n=17)	x
2004-2005	69.8 ± 7.9 (n=42)	68.3 ± 14.7 (n=60)	x
2005-2006	56.0 ± 12.1 (n=22)	57.8 ± 10.4 (n=22)	61.6 ± 12.3 (n=22)
2006-2007	57.3 ± 6.6 (n=15)	64.7 ± 10.5 (n=15)	60.6 ± 15.2 (n=15)
2001-2007	66.0 ± 7.9 (n=150)	64.7± 11.8 (n=181)	61.2 ± 13.5 (n=37)

organic synthesis or evaluation of flow rates in rivers for environmental sampling. In all cases, however, the form of the assessment criteria is well known to the students.

Student performance
An evaluation of the effectiveness of the case study approach is given here by consideration of student performance in oral presentations and reports, together with a comparison with performance in other coursework (laboratory reports) and in examinations. These data (Table 1) have been compiled, uninterrupted, since 2001-02, though examination data is only available for 2005-2006 and 2006-2007. A couple of points emerge from the analysis. Firstly, students perform consistently well in the case study work. Although there is some annual variation in the mean marks for the case study , the combined mean mark (66.0 ± 7.9%) is very typical for coursework at this mid-point of the degree program. Secondly, both the annual and the combined mean marks for the case study assessments (25% of coursework) are extremely similar to the accompanying marks for the laboratory reports (75% of coursework) within the same module. The corresponding marks for the end-of-year examinations (50% of module) are available only for the last two years, with the combined mean mark being slightly lower than those of the two coursework components, although the spread of examination marks is somewhat higher. Both of these features are common for examination-based assessments.

Student feedback is largely anecdotal. Since parallel modules address transferable and professional skills in a more overt manner, the students are acutely aware of the significance of such skills and the importance placed on their development throughout the course. They particularly appreciate the opportunities that case studies give them to advance their skills, commonly citing group work, time management and presentation skills as those areas of greatest significance for them. A more detailed account of this qualitative feedback has been reported previously (Belt et al., 2002).

Stage 3 BSc (Hons) Analytical Chemistry

Background
The Pale Horse is a PBL case study that has been used as part of a Stage 3 or final year module entitled 'Forensic Analysis' since 2001-02. The case study is carried out in small groups (4-5 students per group) over 4 sessions and the groups are assessed via oral presentations and a group report. The remainder of the module is assessed through traditional laboratory reports, which represent 75% of the coursework component, and an examination (50% overall module mark). Thus, the division of assessment marks is the same as for the Stage 2 module described previously.

A detailed description of *The Pale Horse*, including qualitative student feedback, can be found elsewhere (Belt et al., 2002), but it is worth considering an overview here. The case study sets analytical chemistry within the context of a forensic investigation of a (fictitious) suspicious death. The case study begins by setting the scene and introducing the characters involved, which permits a preliminary assessment of any motives for committing a crime. The role of the groups is also defined at the outset together with the intended learning outcomes of the case study in terms of acquisition of subject specific knowledge and development of scientific and transferable skills. Significant attention is also placed on the importance of the assessment criteria at this point.

Assessment criteria
Students are assessed by a combination of an oral presentation and a written report. The assessment criteria (which are identical for both components) require the students to provide a step-by-step rationale for their various analytical requests (evidence/technique), a fully justified solution to the problem (cause of death), an account of their problem-solving strategy, and the role of analytical chemistry in the case study. Thus, the students not only need to work towards a 'best-fit' answer to the problem which is consistent with all of their data, but also to think carefully on the wider implications of their problem-solving. Emphasis is given to these features during the first briefing session including highlighting the

Table 2: Summary of Stage 3 student performance data in case studies, laboratory reports and examinations for 2001-2007. Overall module assessment weightings: Case Study: 12.5%; Laboratory Reports: 37.5%; Exam: 50%.

Year	Case Study (%)	Laboratory reports (%)	Exam (%)
2001-2002	56.6 ± 15.2 (n=22)	70.8 ± 8.5 (n=22)	62.4 ± 11.1 (n=21)
2002-2003	56.7 ± 1.3 (n=15)	69.9 ± 9.8 (n=13)	50.5 ± 11.4 (n=15)
2003-2004	57.0 ± 8.9 (n=29)	77.0 ± 11.2 (n=28)	52.0 ± 9.8 (n=29)
2004-2005	57.5 ± 8.5 (n=13)	79.0 ± 6.1 (n=14)	46.2 ± 6.7 (n=14)
2005-2006	60.3 ± 8.9 (n=22)	76.5 ± 11.4 (n=22)	53.2 ± 14.8 (n=22)
2006-2007	57.0 ± 5.6 (n=19)	73.0 ± 10.8 (n=19)	52.3 ± 12.9 (n=19)
2001-2007	57.5 ± 9.6 (n=120)	74.6 ± 11.0 (n=118)	53.2 ± 13.3 (n=120)

importance of continuous and detailed note-taking to evidence planning, changes of direction, and a detailed rationale for specific requests as the case study progresses.

Student performance
The mean marks for students' assessment marks for the forensic case study, laboratory reports and end-of-module examination are summarised in Table 2. Analysis of these data reveals a number of outcomes. Firstly, the mean marks for the case study, when considered on an annual basis, show little deviation from the overall mean value of 57.5% (2001-2007) indicative of little variation due to differences in abilities of the student cohorts. (There is an even smaller difference between the individual marks for oral presentations and for reports, as expected due to the identical assessment criteria). Consideration of standard deviations from the mean value (57.5 ± 9.6%; n=120) gives a better indication of the range of individual student performances. Similar (small) variations between individual years' marks and collective marks can also be seen for the mean marks from laboratory reports (74.6 ± 11.0%; n=118) and examinations (53.2 ± 13.3%; n=120) although the spread of marks for the latter is greater than that for either of the two coursework components as is common for other modules. Secondly, these annual consistencies observed for mean marks from individual assessment components, conveniently permits comparison between them. Thus, with the exception of 2001-2002 (the first year that the module was run), the mean mark for the case study has always been higher than that of the mean exam mark, and by approximately the same margin (ca. 5-8%). For the collective 6-year period, the case study mark (57.5 ± 9.6%) is 4.3% higher than the mean examination mark (53.2 ± 13.3%); these observations are consistent with common relative performances in coursework and examinations observed in other modules. Thirdly, the mean annual case study marks are found to be always lower than the marks for the laboratory reports, despite the common theme of the module (forensic analysis) and, overall, there is a substantial difference (17.1%) between the mean case study mark (57.5 ± 9.6%) and the mean laboratory report mark (74.6 ± 11.0%) for the whole dataset. Fourthly, with the exception of 2001-2002, the (average) performance falls in the sequence: Laboratory Report > Case Study > Examination, with this sequence corresponding to 61% of students when considered individually.

A qualitative assessment of student feedback has been reported previously (Belt et al., 2002) and this is made more quantitative here. Briefly, 95% of students enjoyed the case study and agreed that it had enabled them to make more sense of theory. Consistent with these figures, 85% disagreed that the case study had not taught them anything new. In terms of process, no students said that their approach was the same at the end of the case study compared to the beginning, with the majority (80%) stating that it was clearly different. When asked about possible changes, 60% of students thought they would have achieved more given more time, although 90% of students claimed to have finished the work on-time. Half the students would have preferred to have gathered their own data via laboratory work and this might make an alternative adaptation of the case study.

Discussion
The collation of the assessment performance data together with its evaluation has been carried out retrospectively so, for the latter, there are no data corresponding to a 'control' experiment. The study is not (strictly speaking) a longitudinal one, and there has not been an initial hypothesis, with experiments designed to test it from the beginning of the analysis. Despite these potential 'research failings', the study possibly benefits from the absence of any preconceived bias towards expected outcomes, and the teaching within the modules has remained largely constant throughout - there is some benefit to teaching the same material every year ! In addition, since Stage 2 cohorts have (largely) become Stage 3 counterparts, with part of the analysis here involving a comparison between different Stages, there is also a degree of continuity or consistency within the study. The tutor for the case study work has remained the same throughout, although a number of tutors have been responsible for assessing laboratory work and examinations.
The performance data for Stage 2 indicate that students perform well for PBL case study work and at least as well as

for other modes of assessment within the same module. Performance in case study work is slightly better than for examinations, a feature which is common to the majority of accompanying modules, and one that has been reported previously (Potter and Overton, 2006). The popularity of the case study approach together with the good performance of students is, of course, pleasing from a tutor's point-of-view, but is perhaps expected given the assessment criteria used for each of the case studies namely, the quality of solutions to problems and clarity of presentations and reports. Thus, although the contextual element and some open-ended nature to the problems within the case studies may not be entirely familiar to the students, the assessment methods almost certainly are.

The performance data for the Stage 3 students reveal some differences. Firstly, the uniformity in performance across different assessment components is not observed. Students perform particularly well when reporting on laboratory work, but achieve lower grades during examinations, a common observation for modules that have both coursework and examination components. However, performance in Stage 3 case study work is not only lower than in examinations as might be expected, but is lower than for laboratory reports, despite the focus of the module on a single theme (Forensic Analysis). This poorer performance in case study work can be seen both annually and overall (Table 2). In addition, the mean case study mark for Stage 3 (57.5 ± 9.6%) is markedly lower than for the corresponding Stage 2 mark (66.0 ± 7.9%), although this difference is not always seen on an annual basis.

It is possible that the lower Stage 3 case study marks might be attributable to students taking the assessed work less seriously than the other elements due to its lower weighting (12.5% of module mark). However, since there is an identical assessment weighting for the Stage 2 module, for which performance in the case studies is good, this explanation seems unlikely. Instead, it is suggested that the relatively poor Stage 3 case study performances are linked to the assessment criteria and the students' responses to them. The Stage 3 case study assessment requires students to provide 'solutions' to the problem and most students respond well in this area by providing good evidence to support their conclusions (c.f. Stage 2 observations). Such abilities to solve problems, even when they are complex or trans-disciplinary, has been identified as one of the most positive learning experiences of PBL in medicine (Gijbers et al., 2005). However, the Stage 3 assessment criteria also require students to evaluate aspects of group methodology and planning, rationales for decision making and, in a wider sense, the role of analytical methods in applied disciplines such as forensic science. Such criteria are probably less familiar to the students, who give insufficient attention to them, despite careful counselling by the tutor in the first session. Of course, it is important that assessment methods align with the teaching approach employed. For PBL, it is recommended that assessments should permit students to "demonstrate understanding of the influence of contextual factors on problem analysis as well as problem solving" (Birenbaum and Dochy, 1996), "argue for their ideas on the basis of various relevant perspectives" (Segers, 1997), and that "the test items ask for more than the knowledge of separate concepts: Integrative knowledge, requiring the integration of relevant ideas and concepts, is stressed" (Segers, 1997). Thus, the case study assessment criteria would appear appropriate given these principles.

In summary, the impact of PBL, particularly within the natural sciences, has focussed traditionally on anecdotal evidence and/or student feedback with little attention placed on quantitative measures. The data presented here indicate that students' performance may be strongly linked to PBL assessment criteria, an observation seen previously with medical students (Dochy et al., 2003; Gijbers et al., 2005).

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For PBL, it is recommended that assessments should permit students to "demonstrate understanding of the influence of contextual factors on problem analysis as well as problem solving"

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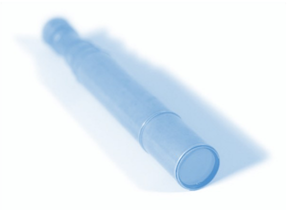

Asking the right questions: Developing diagnostic tests in undergraduate physics

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Abstract
Being able to discover students' conceptions and more importantly alternate- and misconceptions about a topic is vital in order to be able to assess and thus be able to improve student learning. It is well known that this can be achieved via the use of well-designed diagnostic tests, a widely used example of which is the Force Concept Inventory. Creating the right questions in order to form a reliable diagnostic test can be a lengthy and complicated process. This article reports work on a Development Project funded in 2008 to develop such a test for introductory Quantum Mechanics courses in both physics and chemistry. We present details of our methodology, which involves augmenting a 'standard' multiple-choice question set with free-response boxes to determine the reasons for a student choosing a particular answer, and a self-assessment of their level of confidence in their choice. The responses from piloting this initial test in different institutions are used to inform the subsequent refinement of the test, as well as assessing the reliability and validity of the questions. We highlight examples of misconceptions that have been found during the development of the diagnostic tests.

Utility of Diagnostic Tests
Diagnostic tests have been used in a range of different subjects in order to gain a fuller understanding of students' grasp of key concepts. Misconceptions can occur 'when prior knowledge and belief are in conflict with scientific knowledge,'[1] and can cause many problems for students during a course and throughout their degree. It thus seems essential for instructors to uncover these misconceptions since there is strong evidence that these need to be taken into account in order to improve the efficiency of instruction.[2] The Force Concept Inventory[2] is an example of a diagnostic test in classical mechanics that has been shown to uncover many misconceptions that students hold about the subject. This test is a set of multiple–choice questions and is generally given to the students both pre and post instruction. Richard Hake[3] used this diagnostic test and surveyed approximately six thousand students in high schools, colleges and universities in the US. The test was used as a quantitative measure of learning gains from different types of instruction and so was given to the students both pre and post instruction and from this their percentage gains were able to be calculated.[3] It can be interpreted from these results that the test consistently highlighted certain misconceptions, regardless of prior learning of the subject or instructional style. Once a test has been constructed it is important to see how valid and reliable it is. If a test is reliable it is said to be 'consistent within itself and consistent across time.'[4] A test will be valid 'if the skills or knowledge it measures are directly relevant to the stated domain of the test.'[4] There are ways of testing whether a test is reliable and valid and more information can be found in reference 4.

Diagnostic tests have been used in a range of different subjects in order to gain a fuller understanding of students' grasp of key concepts.

Styles of Questions
When designing a diagnostic test that is going to be an effective tool in uncovering any misconceptions to which the students may be subject, it is important to ascertain the origin of these misconceptions. This information can then feed forward into redesigning and improving instruction.

We have employed three different approaches in designing our tests, which consist of three distinct styles of multiple–choice questions. One of the reasons for providing the multiple-choice questions in different styles and media formats, i.e. on paper or online, is so that instructors will be able to utilise the one that suits their needs best. The first style is the standard multiple–choice question. This consists of the question and the selection of possible answers from which the students select. This type of question is widely-used but may not yield information as to why the students are under particular misconceptions. However, it is very easy to deploy online as well as on paper and it is the simplest to analyse.

The second type of multiple-choice question is the free response with confidence level question. This format consists of the standard multiple-choice question followed by a free response text box for the students to write down why they think their selected answer is correct, then a selection of confidence levels for them to choose how confident they feel with their reasoning. An example from our diagnostic test is shown in Figure 1.

This form of question provides the most information about why students may be under a certain misconception. It can also indicate whether the question tests what you think it should test from a student's perspective: this is one aspect of assessing question validity. It does take far longer to analyse than the standard multiple-choice question but is still relatively simple to deploy on paper and online. The responses from this style of test can then feed forward into the creation of the third type of multiple-choice question.

IF YOU DO NOT KNOW THE ANSWER TO A QUESTION PLEASE LEAVE IT BLANK 8

8 Tunneling

The total energy of an electron after it tunnels through a potential energy barrier is...

A ...greater than its energy before tunneling

B ...equal to its energy before tunneling

C ...less than its energy before tunneling

Please state your reasons why you think your selected answer is correct

How confident are you in your reasoning?

Very sure Fairly sure A little unsure Very unsure

Figure 1: An example of a free response with confidence levels multiple-choice question, which was taken from the pilot study for the introductory Quantum Mechanics test.

Two-tier multiple-choice questions[5] are the third style of questions used in diagnostic tests. These can be most effectively created from the information provided from the free response text boxes in the previous style of question. This format provides almost as much information as the previous one as to why students may hold certain misconceptions, but it is far simpler to analyse. An example is shown in Figure 2.

The main potential drawback with this style of question is the fact that students taking the test may use the selection of reasons as to why the answers may be correct in order to assist them to choose their answer. A way of preventing this problem is by deploying this style of question online, separating the answers from the reasons why and preventing students from switching back and forth between the two selections. This would not be possible to prevent when deploying the test on paper, which may thus limit its use.

Designing Questions

In order to find the right questions to construct a well-designed diagnostic test the first step is to find the key concepts on which the test should be based. Starting with a list of the core topics covered in a course it is then possible to create a concept list. Once the key concepts have been determined the questions can then be developed based on these. For the development of our tests, we surveyed a variety of syllabi in both physics and chemistry instruction in quantum mechanics at different institutions. When the question has been created the selection of answers from which the student will choose needs to be carefully designed. Each selection should be both plausible and ideally represent a certain misconception a student may hold. It has been suggested that 'The quality of a multiple-choice question, could be said to be based upon the quality of the distracters, not the quality of the question.'[6]

One measure of the validity of the questions is to employ the use of 'expert validity'. This consists of expert opinions on the face validity (seeing whether the concepts tested are related to the subject) and content validity (coverage of the subject matter) of the items on the test.[4]

Once the questions have been fashioned it is then possible to group them into three general categories: 'Recall', 'Interpret' and 'Apply'.[7] Where 'Recall' questions simply ask the student to recall key facts and definitions, 'Interpret' questions require

Tunneling

The total energy of an electron after it tunnels through a potential energy barrier is...

A. ...greater that its energy before tunneling
B. ...equal to its energy before tunneling
C. ...less than its energy before tunneling

What is the reason for your selected answer?

1. Due to the conservation of energy the electron's energy remains constant
2. Energy is gained from the potential energy barrier
3. The energy of the electron exponentially decays within the barrier
4. Energy is required to tunnel through the barrier and is then dissipated

Figure 2: An example of a two–tier style question taken from the revised question shown in Figure 1.

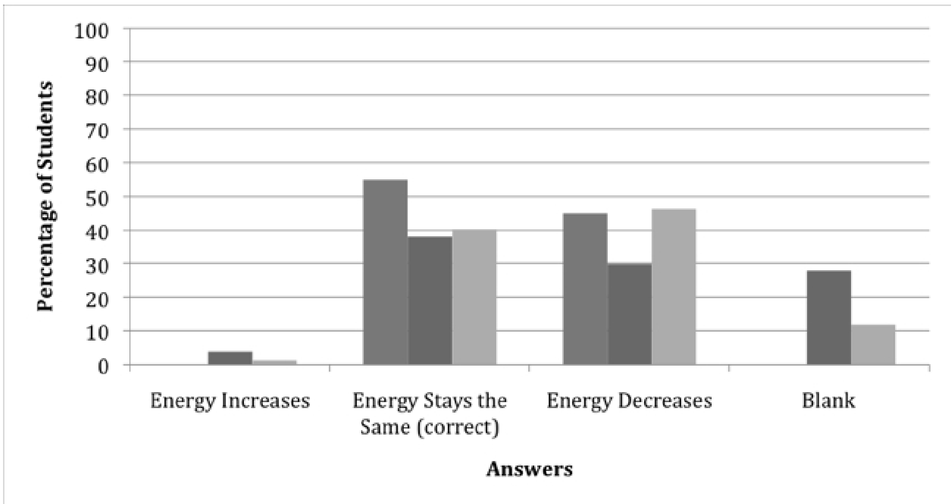

Figure 3: Results from Quantum Tunneling Question (Figure 1) for the three institutions post instruction

students to extrapolate 'already learned material in a qualitative fashion', and 'Apply' questions require both extrapolation and 'numerical manipulation.'[7] Ideally when designing a conceptual diagnostic test, it would be best to have most of the questions residing in the 'Interpret' category.

Piloting the Test
At the University of Edinburgh we have devised two diagnostic tests for introductory Quantum Mechanics in both physics and chemistry. They have both employed the same method of design as explained earlier, where the free response text boxes in the pilot test were used to feed forward into the creation of a two-tier version of the test. This methodology has also been used in the creation of other diagnostic tests at the University of Edinburgh.

The introductory Quantum Mechanics physics pilot test was deployed to second-year Edinburgh University physics students both pre and post instruction. By delivering the test both pre and post it was then possible to ascertain any misconceptions that improve with teaching and those that persist throughout and require further attention. This test has also been deployed to second-year University of Glasgow and University of St Andrews physics students post instruction. From the three institutions there were 134 students who took the test post-instruction. Analysis of these results is on-going and the test is currently being revised to create a two-tier edition.

Revisions of the Tests
Whilst analysing these results it has been seen that there has been very little difference between the spread of results between the various institutions, implying that the different institutions are relatively homogeneous in terms of ability post-instruction on introductory Quantum Mechanics courses and so implying that this diagnostic test is then widely applicable. However, there have been a couple of 'rogue' questions discovered. These have been, for example, where the majority of students have left a question blank. In order to find out more information about students' understanding of these questions and concepts several focus groups have been held. Some of the preliminary analysis directly informed the topics on which questions were based for the focus groups in order to gain clarity. With the information gathered from these groups some of the questions will be revised and others removed from the test.

Misconceptions
The Quantum Mechanics diagnostic test uncovered several misconceptions, one of which is that 'energy decreases when an electron tunnels through a potential energy barrier'. This misconception has also been discovered from the 'Quantum Mechanical Conceptual Survey' at the University of Colorado.[8] It has been prominent throughout all three institutions as well as persisting post-instruction at the University of Edinburgh. This is illustrated in the results obtained from the selected answers to this question (Figure 1) as shown in the graph (Figure 3). Another misconception that was uncovered involved the students confusing the spacing of energy levels of an infinite potential square well with that of a hydrogen atom. This misconception was also prominent throughout all three institutions and did persist post-instruction at the University of Edinburgh.

Preliminary Conclusions
Diagnostic tests have been shown to be exceptionally useful in exposing students' conceptions of a subject. However, it is a lengthy and time-consuming process in order to develop them. Although the tests will still need further revisions in the future, they are still able to demonstrate to instructors what concepts students are and are not understanding in their course. The results from these tests will hopefully be carried forward into any revisions of the courses in the future.
The project will be completed by Autumn 2009 and so the quantum mechanics diagnostic, which is currently under revision, should be available mid-Sept. It will be made available from the PSC Development Project website for this project:
http://www.heacademy.ac.uk/physsci/projects/detail/development_projects_2008/bates

Acknowledgements
We would like to thank all staff and students at the institutions who contributed to the project, as well as both the Physical Sciences Subject Centre and the Principal's Teaching Award Scheme at the University of Edinburgh for funding.

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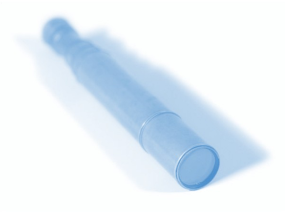

The design of an image bank

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Abstract
Image Banks, which are collections of images with associated data and captions, are a valuable teaching tool for Astronomy courses at the Open University. Until now web pages have been created for each image and its associated information. This paper examines how a database, front-ended by a multimedia authoring tool, can provide a much more flexible and maintainable architecture for producing Image Banks. Accessibility issues are discussed.

Introduction
Image Banks are used within several science courses[1,2,3] presented by the Open University. They typically consist of between one and six hundred images with titles, captions (often running to a thousand words or more), dates, credits and scale information. The idea is that these images can be browsed by logical sections or by searches on the captions. The student might be investigating a certain kind of object. Sometimes exercises can be carried out on the images such as measurement of a particular feature. The image banks are perceived as being vital components of the relevant courses and are well received by the students. They offer a way to deliver large volumes of information that are based around images in a way that can easily be accessed and searched. Many of our subjects contain large numbers of educationally valuable images that would be difficult to produce in book form, due to the volume and regular updating of the images. In particular, astronomical images are constantly being updated with new discoveries and better resolution images and images taken at different wavelengths. For these reasons we perceive image banks as being a generally applicable teaching tool which might be used across many subject areas where large numbers of images and associated captions are a beneficial resource.

The image banks are perceived as being vital components of the relevant courses and are well received by the students. They offer a way to deliver large volumes of information that are based around images in a way that can easily be accessed and searched.

Until recently these image banks have been created using Dreamweaver, a webpage authoring package, to create a set of individual web-pages that incorporate the image and the various text fields. Hence a particular image and its various text fields will become a single web page. The web-page approach has some advantages: everyone has a browser with which they can view the image bank, so there's nothing to install and the image bank will run straight from the CD/DVD. Also screen readers such as JAWS (Job Access With Speech) are able to read the text for partially sighted and blind users and take advantage of text used in Alt-tag fields that are commonly used to describe fields on web pages.

It is foreseen that Image Banks will be used more widely due to the successful use of those already in place and the need to provide the students with a tool which they can use alongside the main course material that supports their own exploration of additional material. Thus a more generic approach to creating and maintaining them is seen as highly desirable. Ideally, we would like to have a viewer which can be used with any set of images so that the viewer and the sets of data it can use can be maintained independently of each other.

Requirements for an Image Bank Viewer.
1. A generic approach can be taken to viewing the images that does not require each image to be individually processed to produce a web-page or some such viewing medium. It shouldn't be necessary to produce pages that list all the hyperlinks to sections and subsections. These should be generated automatically from the data.
2. The viewer must not rely on the user having any particular application installed unless this is something that the user must have anyway (such as a web browser).
3. It should not need to be installed, but should run directly from the CD/DVD as a matter of convenience.
4. We want to be able to pan and zoom images.
5. Measurement tools should be incorporated into the viewer.
6. Accessibility should be addressed.

Proposing a solution

The first requirement suggests a database approach with each image being associated with a record in a table. This table would store all the textual items and give the path to the particular image. A page can then be created that can display *any* of the images with its associated data fields. Additionally, pages giving hyperlinks to each of the sections can be generated at run-time.

The second requirement rules out using PowerPoint, Word for example, as either the application delivery mechanism or as a software component for viewing images or documents.

The third requirement makes component-based applications unusable. Hence, VB, C, C++ and Delphi are all going to be problematic as development tools.

Requirement 4 might be met in one of several ways. A multi-media authoring package might be expected to provide this as a primitive function, but if not, any such environment would be capable of providing this given the ability to program in some embedded language such as Java or C.

Requirement 5 can be satisfied just a long as a sufficient amount of programming is available to provide the necessary calculations on the image positions.

Requirement 6 will be discussed in its own section 'Accessibility'.

Database Connectivity

It is clear that an Image Bank that is required to work with various collections of images and their associated data should be a database application as databases are designed to solve the problem of efficiently storing and giving access to collections of related data. With the added requirements of needing to operate directly from CD/DVD with no installation then a multimedia development tool with ODBC (Open DataBase Connectivity) is going to be the only solution. These requirements are met by the Opus Professional Multimedia development environment[4]. This has the additional advantage of permitting programming in Java. ODBC drivers, which are available as part of the Windows Operating System, give access to a huge range of databases some of which are not actually genuine databases at all, but are just treated as such. This is achieved via SQL (Standard Query Language)[5]. This allows us to select fields from tables of information, apply conditions on whatever is selected and impose ordering on retrieved datasets. Whether we have a genuine database system such as Oracle, or a table of data in the form of an Excel spreadsheet is of little consequence as we access both using identical SQL strings. There are questions of efficiency and sharing which commercial database systems address but simply don't apply here where we have a relatively small, non-shared dataset. A fully-fledged database system such as Oracle would not be feasible here. It couldn't be provided on a executable CD/DVD, it would require the user to have Oracle installed, and it's very expensive amongst many other reasons. A PC based system such as Access would provide all that we want, but again it could not be used on a executable CD as it would need to create a log file at run time which could not be achieved on a read-only device. Hence, an Excel spreadsheet will serve as the database, with the connection to the application provided by a suitable ODBC driver.

> *'The CD-ROM (with its moving planetary images) and textbook images were all beautifully presented and shown in great clarity and colour'*

Accessibility

It is certainly not clear that Opus can provide the necessary Accessibility features as its controls do not even support a tab ordering which would allow it to be controlled via the keyboard rather than the mouse. Some experimentation has shown that tab-ordering can be achieved by programming it in for each screen, but it is surprisingly clumsy and elaborate. However, it is an easy matter to use keys for the same functions as on-screen buttons. For example, the PgDn key can be used instead of mouse-clicking on the Page Forward button.

Screen readers such as JAWS need access to the underlying text in order to be able to render it as speech. This is only usually the case for the major Microsoft applications like Word where it has been specially provided for or in HTML documents where the source text is not encoded (surprisingly screen readers never do screen-scraping coupled with Optical Character Recognition, they always require special hooks to be provided that give them access to the underlying text). JAWS cannot be directly interfaced to the database. To enable JAWS to read the text it would be necessary for the Image Bank software to extract the data from the database and then present the text in an HTML document or some other format that JAWS could access.

In addition to tools such as JAWS which are aimed squarely at the partially sighted or blind user, there are a multitude of Text To Speech (TTS) applications available. A common facility is being able to paste text into them and have it converted to WAV or MP3 format, i.e. the text is rendered into a spoken form and stored as a sound file in one of the Windows standard formats. The latest generation of TTS programs, such as Natural Reader from AT&T[6] is really very good with a tonal quality that is good enough to be used where students would prefer to listen to the captions rather than read them. Thus we can take all the text from our captions and other fields and translate them to sound files that can be played by the multimedia application. Additionally we can make help on navigating and using the application available as both text and speech. This actually works better than using an application like JAWS which tends to deliver an unnecessarily large amount of information about the current window. Whereas, our application restricts itself to exactly what the blind user needs to know.

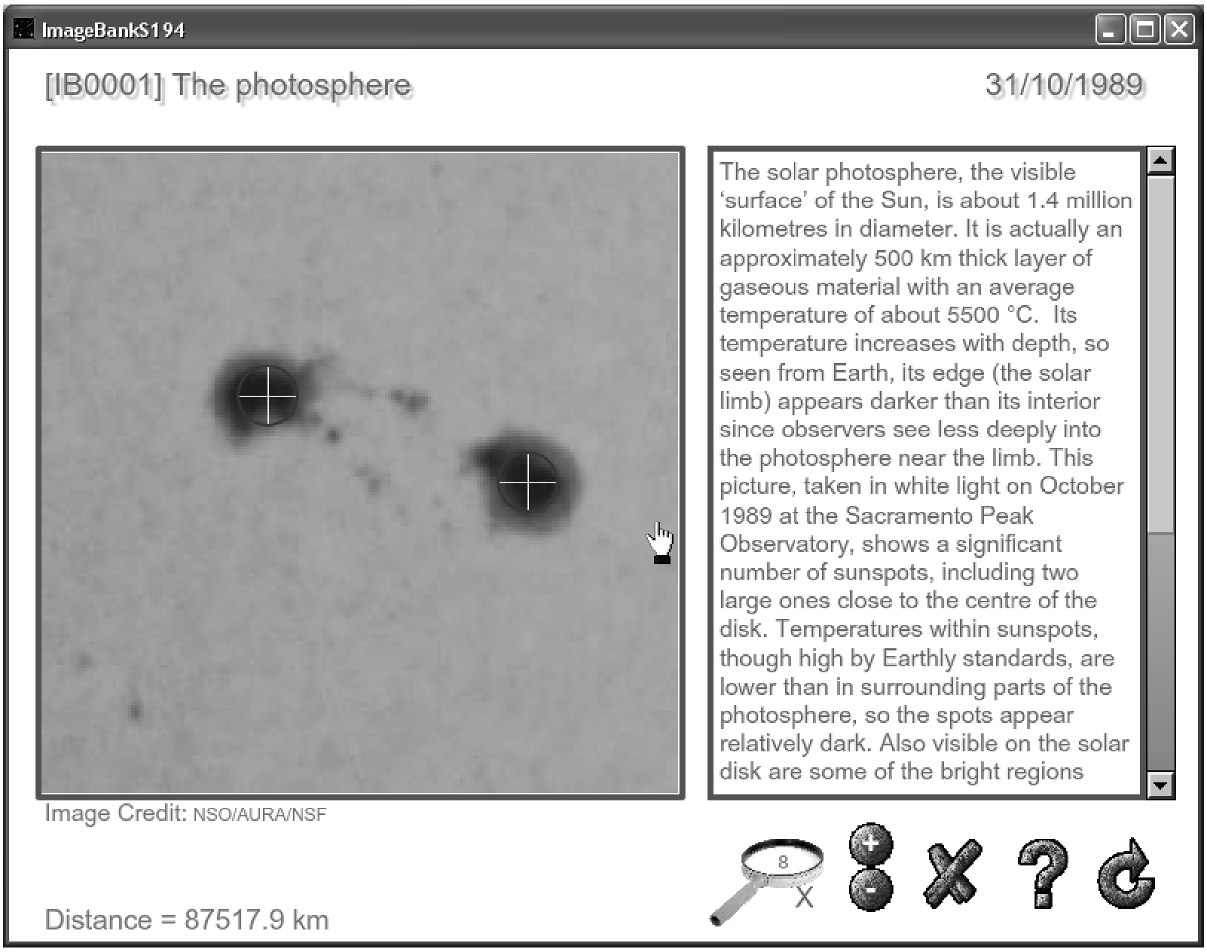

Fig 1: The Image Bank viewer which shows the measurement of the distance between two sunspots

DeskBot[7] is a freeware clipboard reader that allows the user to configure how the text is to be read. It is only necessary for the application to copy the text to the clipboard for the DeskBot reader to start reading the text to the user. The user can also ask for the text to be displayed at any size and at a given number of lines at a time. This is a very elegant solution as the application, upon extracting the text from the database for the particular image, can at the same time copy this text to the clipboard making it instantly available to the DeskBot reader which renders it as audible.

Formatted text

There is a requirement for some formatting of the text such as subscripts used in chemical formulae and superscripts to indicate numerical powers. These are surprisingly awkward to deal with. A superscript character is not simply an item of a character set. It is such an item plus additional attributes set for this item. So when a character string is read in from a database character field there is no such attribute data and any such formatting simply does not exist.

Unicode gives us the capability of storing wide character sets, but these do not address consistently the need for superscripts and subscripts. Typically some values such as 2 for squared and 3 for cubed will exist but little else. For this reason Unicode is simply a red-herring.

The options that remain are to:

- Mark all cases of special formatting with escape sequences so that the formatting can be applied once the data has been extracted into the application.
- Store the data in a standard format such as RTF (Rich Text Format).

Perhaps surprisingly SQL based databases do not have the capability to store any formatted text directly. There is no formatted text type in the SQL Standard[5]. If the second option is to be used then a binary type is needed for a database field which is to store it. Or store each of the captions in its own formatted file which is then referenced in the database. Having stored it, as binary (which precludes the use of text files or spreadsheets as our database source, something that we might wish to do if we were to use ODBC) then we need to be able to retrieve the formatted text and then display it in its formatted form.

We also need to be mindful that we might wish to change other attributes of the text, such as size for readability. Opus will allow us to use a document viewer to view any Active X document (ActiveX is simply the technology that allows the document to be opened within another application). However, this requires the application that views this format to be present on the end-user's machine. This clearly cannot be guaranteed in the case of Word or Excel. The only viable format is RTF which can be displayed without recourse to an external application.

Image Bank Design

The original image bank was designed for the Introduction to Astronomy Course (S194)[1]. The design uses an Excel spreadsheet as the database. The Image Bank application is written in Opus[4] and used an ODBC connection to the database. The database stores the captions, the image file paths and other information such as credits and image size. From this spreadsheet all the pages, the section and subsection headings are automatically generated by the viewer. In the first instance, superscripts and subscripts were catered for using escape sequences. This is not ideal and in future we will store the captions in individual RTF files with a reference to them in the caption field of the database.

Features, such as being able to do on-screen measurements, panning and zooming were exceptionally easy to program into the application using the underlying Java language and the available set of multimedia functions.

Features, such as being able to do on-screen measurements, panning and zooming were exceptionally easy to program into the application using the underlying Java language and the available set of multimedia functions.

Extending the design

Since building the first image bank for the Introduction to Astronomy course, several more have been built for the Planets course (S196)[3] and for the Understanding the Weather course (S189)[2]. These two courses added to the requirements. In particular hyperlinks were required between images and captions. Also more control over formatting the captions was required. These were both provided for by introducing new escape sequences into the text.

We are also now looking at the possibility of generating the final image bank in different formats. Currently we use the Opus front-end to access the database on a disk. This means that to update the images or the captions means re-mastering the disk. However, with all the data stored in a central database we could easily create an application capable of generating HTML pages from the contents of the database that could be updated without any need for updating student copies.

Student feedback

The students' reactions have not been formally evaluated, but comments posted on the students' forums indicate a general appreciation of the image banks. Here are some from the S196 Planets – and introduction course:

> 'The CD-ROM (with its moving planetary images) and textbook images were all beautifully presented and shown in great clarity and colour'
> 'The course is challenging, interesting and loaded with up -to-date info and images.'

And from the S194 – Introduction to astronomy course:

> '…while the CD-ROM images formed an excellent complement to the course book…'
> '…beautifully illustrated course materials.'

Conclusions

A high-level multimedia authoring tool coupled to a database has proved an excellent architecture for the design of the Image Bank. The image bank has been used by many hundreds of students and has proved to be robust with very few issues arising. We have since developed several more image banks that have demonstrated the advantages of this architecture and have introduced new facilities. This has shown that this architecture is not limited to astronomical images but is suitable for a wide range of images with associated captions. We are now looking at designing a Resource Library from which Image Banks for different courses can be automatically generated from the department's entire collection of image and image-related data. This will require the course editor to simply select the images required for the course causing the entire CD/DVD image to be created. This will remove the hard work currently needed to create a new Image Bank and also remove the possibilities for errors. This work has demonstrated that simply collecting relevant images is straightforward but collecting them with appropriate captions, scales, copyright information and relevant dates needs substantial resources.

Using a database to store the image data gives us a very flexible approach and if necessary we can extend our use of the data to automatically generating HTML pages. As we are moving towards more web content orientated courses this will almost certainly be a future enhancement.

Although we haven't as yet incorporated the text to speech technology into our current version the effectiveness of this approach is manifestly obvious. Our students can spend their time looking at the images instead of reading the text. Additionally we can provide instructions for using the package as speech generated directly from the Help text. Both the Natural Reader software and the DeskBot approaches have been tried. We abandoned Natural Reader because of licensing reasons, but DeskBot has proved to be very easy to use and highly effective and I would expect it to be incorporated in future versions of the image bank.

Acknowledgements
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The images and captions for the S189 – Understanding the weather course were collated and edited by Shelagh Ross and Stephen Lewis of the Open University.

The images and captions for the S196 – Planets – an introduction course were collated and edited by David Rothery of the Open University.

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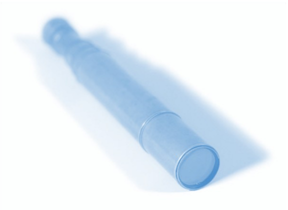
A high-level multimedia authoring tool coupled to a database has proved an excellent architecture for the design of the Image Bank. The image bank has been used by many hundreds of students and has proved to be robust with very few issues arising.



Making physics a smash hit: The use of popular culture in science outreach

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Abstract

This paper examines the incorporation of popular culture into science outreach activities as a means of improving the engagement level of secondary school pupils. Two activities make up the case studies discussed within this paper: 'The Science of Sound' and 'The Music Festival'. Both case studies utilise the creation and consumption of popular music as a means to; convey physics principles; promote the continued study of physics and raise awareness of the broad range of careers that physics graduates can pursue. Consultation with a range of stakeholders involved in the development, delivery, and participation in the case study activities has been undertaken. This includes a focus group with participating Year 10 students and interviews with secondary school teachers and outreach coordinators. The purpose of this paper is to explore the advantages, disadvantages, and challenges in using popular culture to stimulate engagement in this way, and to share best practise to aid the effective delivery of similar initiatives.

Introduction

The importance of developing a workforce which is highly skilled in Science, Technology, Engineering and Maths (STEM) to the future prosperity of the UK economy was brought into focus in 2007 by Lord Sainsbury's review of the Government's Science and Innovation Policy[1]. More recently, research by the Confederation of British Industry has indicated that, despite current economic conditions, the demand for STEM graduates remains high: with nine out of ten firms employing STEM skilled people and four out of ten firms preferring STEM degrees to any other subject. As such, remuneration for STEM graduates remains relatively substantial, with an average starting salary of £22,000 for a graduate scientist[2]. Yet, against this backdrop of opportunity and reward, the number of students pursing STEM subjects within Higher Education remains low, with only 13% of university students studying the core STEM disciplines of physics, biology, chemistry, maths, engineering and technology[3].

The importance of developing a workforce which is highly skilled in Science, Technology, Engineering and Maths (STEM) to the future prosperity of the UK economy was brought into focus in 2007 by Lord Sainsbury's review of the Government's Science and Innovation Policy

This paper considers two science outreach activities delivered within secondary schools in an attempt to increase participation levels in physics within Higher Education. More specifically, this paper explores the use of popular culture in such activities - explicitly the creation and/or consumption of music - as a vehicle to; convey physics principles; promote the study of physics, and; raise awareness of the broad range of careers that physics graduates can pursue. The aim of this paper is to investigate whether incorporating popular culture into science outreach helps to increase the engagement level of participating pupils and also to highlight potential pitfalls in this approach.

In the following section of this paper a brief overview of the two outreach activities is provided. This is followed by a discussion section which has been structured to communicate the opinions expressed by a range of stakeholders. Research for this paper has included focus groups with secondary school pupils and interviews with secondary school teachers and the outreach coordinators. The final section of this paper highlights the main conclusions of this research and presents best practise to aid the effective and efficient delivery of similar initiatives.

Case studies

Two outreach activities make up the case studies discussed in this paper: 'The Science of Sound' and 'The Music Festival', a summary of each activity is presented in figures one and two respectively.

The Science of Sound

Duration	Two hour workshop
Capacity	Up to 20 pupils
Year group	10 and 11
Description	*'The Science of Sound' focuses on the link between electronic music production and physics. Pupils alternate between producing their own music (using commercially available music production software) and learning about the physics principles that will improve their compositions, such as bit-depth and sampling frequency when recording, or the artificial addition of reverberations during production.*
Academic content	• Creation of sound • Parameters of sound waves • Propagation of sound waves • Analogue and digital signals • Sampling: Analogue to digital single conversion

Figure 1: Summary of 'The Science of Sound'

Discussion

Secondary school pupils

Many of the pupils that participated in the focus groups, or completed activity evaluation forms, expressed that the cultural focus of the outreach activities featured in this paper did indeed make the activities 'more interesting' since the physics was made applicable to their own interests. Certainly many of the pupils accurately recalled the physics concepts conveyed during the outreach work, despite six months having passed since the events. It is worth noting that in defining their level of 'interest', several pupils made reference to the minimal provision of practical sessions in their school based physics lessons. This is important, since it has been argued, most recently by the Children, Schools and Families Commitee[4], that education and in particular science education, may have suffered at the hands of an overly-prescriptive National Curriculum which has reduced teachers' capacity and confidence in delivering enriching experimental sessions.

Many pupils felt the cultural focus of the outreach activities had widened their perception of physics based careers, and were surprised to learn that a career in physics was not necessarily constrained to a laboratory. Indeed many pupils were interested to hear that an understanding of physics was important in jobs which they perceived to be quite distant from

The Music Festival

Duration	One full school day
Capacity	12 teams of six
Year group	10
Description	*'The Music Festival' revolves around the physics in music festival production. Pupils adopt a specialist role within teams and develop a proposal for running a music festival. Team roles include Project Manager, Sound Engineer, Lighting Engineer, Health and Safety Manager, Electrical Design Engineer and Construction Design Engineer.*
Academic content	• Properties of sound • Properties of light • Electrical power • Optical power • Digital control

Figure 2: Summary of 'The Music Festival'

science: such as music production or the running of music festivals. The lack of informative STEM careers advice for secondary school pupils has previously been cited as a potential contributing factor to low STEM numbers within Higher Education[5]. Certainly anecdotal evidence from the University of Leeds 'Reach for Excellence' programme indicates that the majority of students studying the sciences at A-Level tend to pursue subjects which they perceive lead to clearer defined career opportunities: medicine and dentistry being the preferred option[6]. Hence, it appears of considerable value that in addition to conveying academic concepts, science outreach initiatives continue to educate pupils about the broad range of career opportunities available to STEM graduates.

On a negative note, a few pupils expressed scepticism over how effective the outreach activities had been at connecting with their popular culture. This was particularly applicable for 'The Science of Sound', in which pupils use short clips of music (termed audio loops) to construct their musical compositions. Whilst every effort was made to cater for the wide range of musical tastes amongst young people, on occasion pupils were unhappy with the genres of audio loops available, and this subsequently acted as a barrier in engaging the pupils in the workshop content. This highlighted the importance of consulting, where possible, with secondary school pupils during the development stage of activities, since 'missing the mark' with cultural references will hinder the effectiveness of an activity as opposed to aiding it.

... making concepts and material applicable to learners is good teaching practise, and consequently teachers did believe that popular culture could 'be used effectively to capture students' interest and imagination'.

Finally, it was evident from observing the activities, that whilst the majority of pupils appreciated the association between science and popular culture, a minority of pupils were content to let the cultural element of the activities act as a distraction from the science. It was therefore important to emphasis the interdependence between the popular culture and the science concepts - thus making the science unavoidable. A good example of such interdependence is the use of musical effects, such as reverb, within 'The Science of Sound'. Reverb units are used to artificially add reverberations to music during production and can influence the style of the music considerably. However, to understand the controls on a reverberation unit requires a reasonable level of knowledge of reverberate fields, which offers ample scope to explore a variety of physics concepts.

Secondary School Teachers and Outreach Coordinators
Of those teachers that gave their opinions to contribute to this research, the vast majority expressed a strong support for the delivery of science outreach within their schools. It was voiced that the school based provision of equivalent initiatives was often not feasible in terms of the time required to develop such activities or the availability of resources. Hence teachers were pleased to be enriching their learners' education by means of help from external organisations. Furthermore some teachers remarked that their own knowledge of physics careers had benefit from overhearing the content of the outreach activities, this is not entirely surprising given 75% of English schools do not have any specialist physics teachers[7].

On the topic of using popular culture within science outreach; on the whole teachers and outreach coordinators felt that pupils did recognise, and appreciated, any attempt to relate material to the pupils' personnel interests. Indeed making concepts and material applicable to learners is good teaching practise, and consequently teachers did believe that popular culture could 'be used effectively to capture students' interest and imagination'. In addition, several teachers pointed out that highlighting the link between subjects, including Science, Mathematics, ICT and Music, assists cross-curricular learning and thus enriches the teaching efforts for a range of school departments.

The main area of concern for a few teachers was ensuring that a suitable balance was struck between science and popular culture: to ensure the 'science wasn't lost' or the 'depth of scientific understanding compromised'. However, this was not a universal opinion held by all teachers and in direct contrast it was also highlighted that the activities' academic depth was 'not a primary consideration' since the activities would be used as 'an extension and to generate interest' as opposed to a primary teaching tool. Outreach coordinators tended to support the latter of these opinions, highlighting that the most successful activities are those which cover different material to that in class and, above all, are fun to participate in.

Finally, several teachers echoed the sentiments of pupils in that they raised concern about using pupils' popular culture without risk of 'missing the mark' and thus actually creating a barrier to learning with 'out of date' cultural references.

Observations

- It can be concluded from this paper that incorporating popular culture into science outreach activities can be advantageous in terms of increasing pupils' engagement.

- It is apparent from the opinions of the pupils who participated in this research that integrating popular culture into science outreach can be of value in countering misconceptions pupils' hold of STEM careers.

Specifically, many pupils were surprised to learn of the broad range of careers available to STEM graduates and that such careers were not constrained to a laboratory setting.

- This research has indicated that care must be taken when employing popular culture within science outreach, since 'missing the mark' with cultural reference can hinder engagement as opposed to promoting it.

- When developing outreach activities, effort should be made to 'design in' interdependence between the scientific concepts and elements of popular culture. Furthermore this interdependence should be emphasised during delivery of the activity; thus making an understanding of the scientific concepts integral to fulfilling the wider aims of the activity.

- Adequate and appropriate consultation during the activity development stage provides exposure to the requirements of teachers and affords a valuable opportunity to ensure the uses of cultural references are appropriate to the target cohort of pupils. In addition, a willingness to learn from feedback by iteratively refining activities and updating cultural references will ensure such initiatives are continually improved.

This research has indicated that care must be taken when employing popular culture within science outreach, since 'missing the mark' with cultural reference can hinder engagement as opposed to promoting it.

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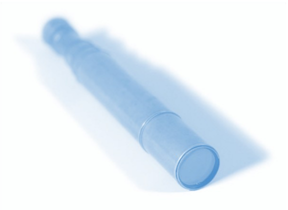

Mapping the transition - Content and pedagogy across the school-university boundary

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Abstract

The period of transition for students from school to university is of great importance, however it is also potentially fraught with difficulties. Incoming students are faced with a study environment very different to anything they have known before and often face a steep learning curve of new study skills and learning methods in order to keep afloat. Whilst these factors are well recognised and have been addressed in literature, there is a growing recognition of the fact that how students perceive their chosen subject has a large impact on how they perform. In fact it has been suggested that students' expectations of a subject may be better predictors of performance in tertiary education than the previous performance of students in school examinations.

This article looks at the application of the CLASS (Colorado Learning Attitudes about Science) Survey at the University of Edinburgh and in selected schools across the UK. The survey allows the opinions and perspectives of students to be compared to those of expert physicists and thus the students' levels of expert-like thinking to be gauged. At the University of Edinburgh the first year physics class, comprising of both Physics students and others taking physics as a complementary course, were surveyed before teaching began and again at the end of first year. In schools, students were surveyed towards the end of their last year of school.

The retention of students in the STEM subjects is of great concern for universities, employers and the government.

Introduction

The retention of students in the STEM subjects is of great concern for universities, employers and the government. In the sciences a "leaky pipe" effect is seen with students dropping out at every stage of their degrees, although most commonly in the early years of their studies. This is especially prevalent in the first year at university where students are adapting to a very different style of teaching and learning.

There is evidence that the way students think about a subject has a profound effect on performance in that subject. It has been suggested that from as early as primary school children develop misconceptions which can shape their attitudes and beliefs of how they view science in general[1]. It has long been established that external social factors and stereotypes create a series of beliefs in students that can affect performance[2]. In fact it has been suggested in previous research that attitudes and beliefs may be a better indicator of their ability than examination results[3]. This has lead to increased research into students' attitudes and beliefs in a variety of subject disciplines.

In the area of Physics, one instrument that has been widely used to examine student attitudes is the Colorado Learning Attitudes about Science Survey (CLASS). This measures the attitudes and beliefs of university students through a series of attitudinal questions and calculates their level of "expert-like" thinking by comparing the answers to those of physics professors and other professional physicists. The survey has been used at many institutions across North America but has been far less widely adopted in the UK. The survey is usually administered both before and after a specific course is taught, or period of instruction, thus allowing the effect of the course on students' attitudes to be assessed through the shift in the students' answers.

The School of Physics and Astronomy at the University of Edinburgh has a very large first year class comprising students taking Physics degrees and those taking the course as an elective. It is a highly successful course, with positive student feedback and clear student gains in conceptual understanding, as evidenced by pre- and post- application of standard diagnostic tests. The students are taught using interactive lectures utilising personal response systems (or "clickers") and in weekly three hour workshops, encouraging group work and discussion about physics ideas and concepts.

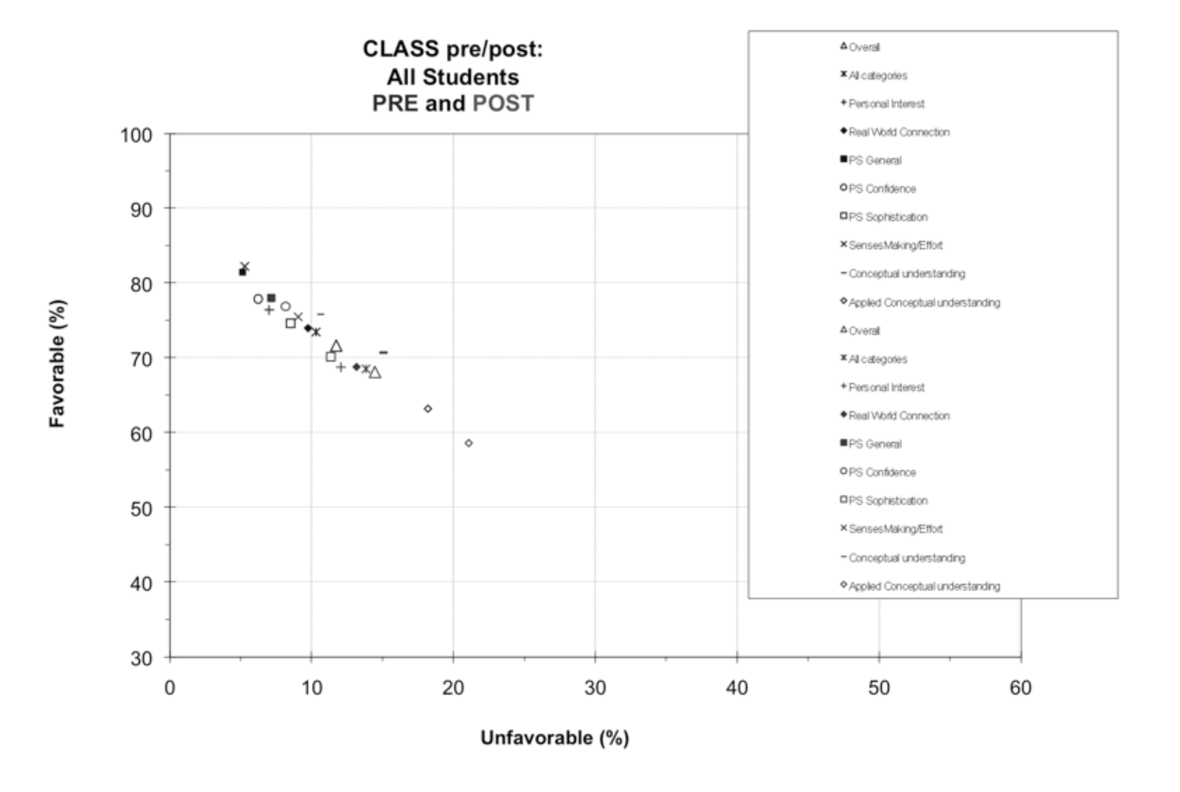

Figure 1: Pre and post teaching shifts in attitudes and beliefs

The class comprises over three hundred students. They are from a variety of educational backgrounds although the vast majority have either come or from the Scottish system of Highers and Advanced Highers or from the English, Welsh and Northern Irish school system of A levels. The incoming students have high examination results from school with all students having an A or B in physics and mathematics at the highest level studied.

The CLASS Survey

Based on a previous attitudinal survey, the Maryland Physics Experience survey (MPEX)[4], CLASS has been developed by the Physics Education Research group at the University of Colorado[3]. It consists of 42 statements, each of which is graded on a five point Likert scale, varying from strong agreement to strong disagreement with the statement. The questions are not a test of physics knowledge but of student attitudes and beliefs about the subject and how it is practiced. The questions are split into 8 categories which are as follows; Real world connections, Personal interest, Sense-making/ effort, Conceptual connections, Applied conceptual understanding, Problem solving (general), Problem solving sophistication and Problem solving confidence. Some questions can fall into several of the categories.

The survey has gone through rigorous processes to check its validity as an instrument. Amongst these are checks of the quality of the data - students must answer a “failsafe” question to ascertain if they are reading the questions and must also answer a certain percentage of the questions for their answers to be included. If the data fails either of these checks it is automatically discounted. The survey has been given to thousands of students across North America, both physics majors and non-physics majors. The survey was also given to academic staff at Colorado University to develop what was seen as an “Expert” response to the questions. Once a consensus had been reached this expert answer was used as a comparison to student responses in order for students’ level of expert-like thinking to be calculated as a percentage.

Delivery of the survey is usually pre and post first year instruction so that the shifts in expert-like thinking are as a direct result of students’ first year of university based learning. Nearly all published studies show that student “expertness” shows a marked decrease after a year of university study[4].

CLASS at Edinburgh

The CLASS survey was given to all of the new students in their first week at the university and again in their last week of teaching. Of the 300 students enrolled in the course 150 students took both surveys and passed the data quality checks so all results shown are for a data set of 150. Each of the 42 individual questions was analysed for the whole class in order to show the shifts in expert-like thinking for the whole cohort.

The graph in Fig. 1 illustrates the results for all students and all question categories. It is sometimes referred to as ‘an agree-disagree’ plot, as it represents a measure of to what extent student responses agree (are favourable) or disagree (unfavourable) when compared to expert responses. If student responses were to become more favourable/ expert-like, there would be a shift towards the top left hand corner of the graph. The different shaped markers are for each of the eight categories mentioned previously.

	Pre (%)	Post (%)
Overall	72	68
Personal Interest	76	69
Real World Connection	74	69

Table 1: Pre and Post Teaching Shifts in selected categories

Simply from looking at the graph (Fig. 1) it can be seen that there is consistent decrease in the students' level of "expertness" across all categories. Quantitatively, there is a change in their favourable responses over all questions from 72% to 68%, in the category on Personal Interest from 76% to 69% and in the category on Real world connection from 74% to 69% (Table 1.)

These results are however still high, pre and post instruction, compared to those seen in previous studies using the same instrument[3]. After discussion with one of the authors of the survey it is thought that these higher values reflect the differences between the North American and British education systems.

As mentioned previously each of the 42 statements was analysed for the whole class to determine the shift in attitude. It was then assessed as to whether these shifts were statistically significant rather than random variations in the mean to be expected in the sample. If it was found to be a significant shift the result was classed as either "Novice" or "Expert". If the students have become less expert they are classed as "Novice" and "Expert" if they have become more so. Out of 42 statements the class showed statistically significant shifts in 13 questions, becoming more novice-like in 11 questions and more expert in 2.

Fig. 2 shows the differences in the pre and post teaching results for just one of the statements showing a statistically significant shift towards Novice-like thinking, "The subject of Physics had little relation to what I experience in the real world". This is a statement that the expert response disagree with, however the first year students have shown a 10% increase in agreement.

The two questions the students became more expert-like in were both issues that are specifically addressed by the course design at Edinburgh. They were:

"To understand Physics I discuss it with friends and other students"

and

"It is possible to explain Physics without mathematical formu-lae"

The first statement is most likely a consequence of the collaborative working environment created by the workshop system at Edinburgh. The nature of the workshops means that the students have to discuss problems as a group and work on problem solving together. The course also requires students must be able to qualitatively explain all mathematics and calculations used: the students lose marks if they fail to do so.

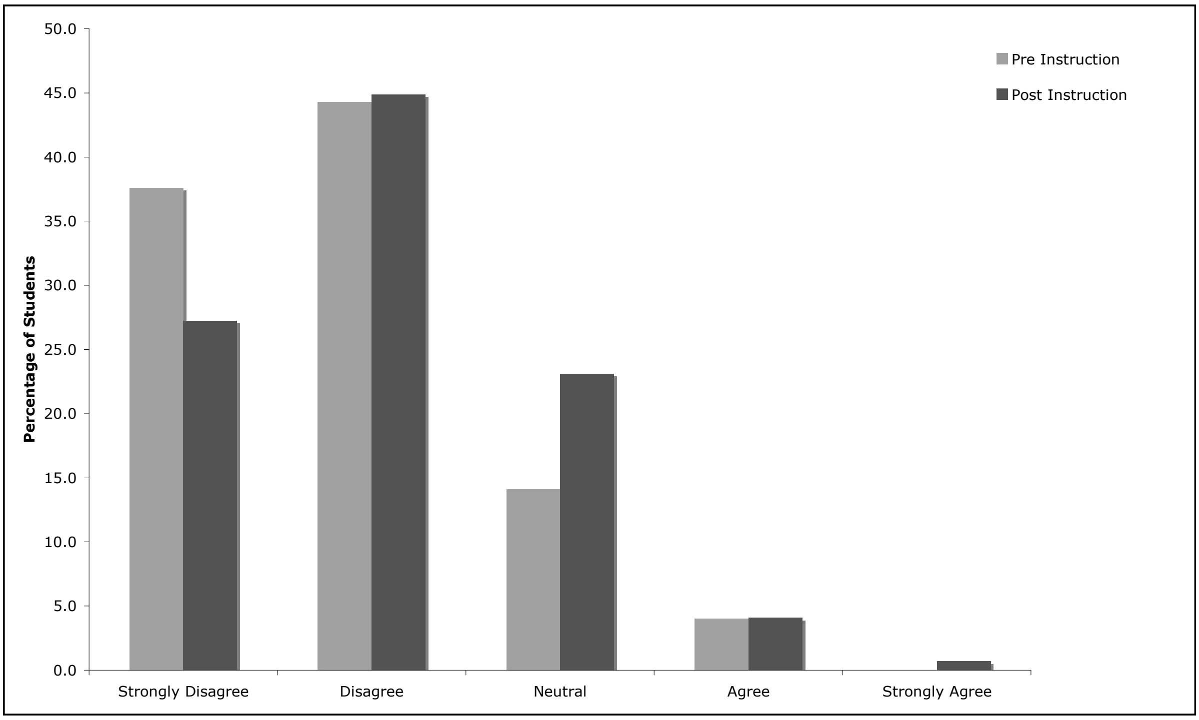

Figure 2: The subject of Physics has little relation to what I experience in the outside world

Further analysis was then carried out with the data in order to look at the differences between the physics majors and non-majors and also the differences between male and female students.

In terms of degree choice it was shown that physics students do not show a statistically significant change in their levels of expert-like thinking. In contrast the non-majors showed a lower starting level (despite satisfying the same entry requirements as the physics majors) and a very significant drop in expert-like thinking over the same period of instruction. These results are illustrated in Figure 3.

Conclusion
The results of the CLASS survey at Edinburgh are very much in line with those recorded at other institutions that have completed the survey. A decline in the students' level of expert-like thinking is recorded in all of the eight categories of interest, including problem solving, personal interest and real world connections. Somewhat surprisingly, we have found that a course can be successful, provide clear student gains in conceptual understanding, be well received by students and still negatively affect students' attitudes and beliefs towards the subject.

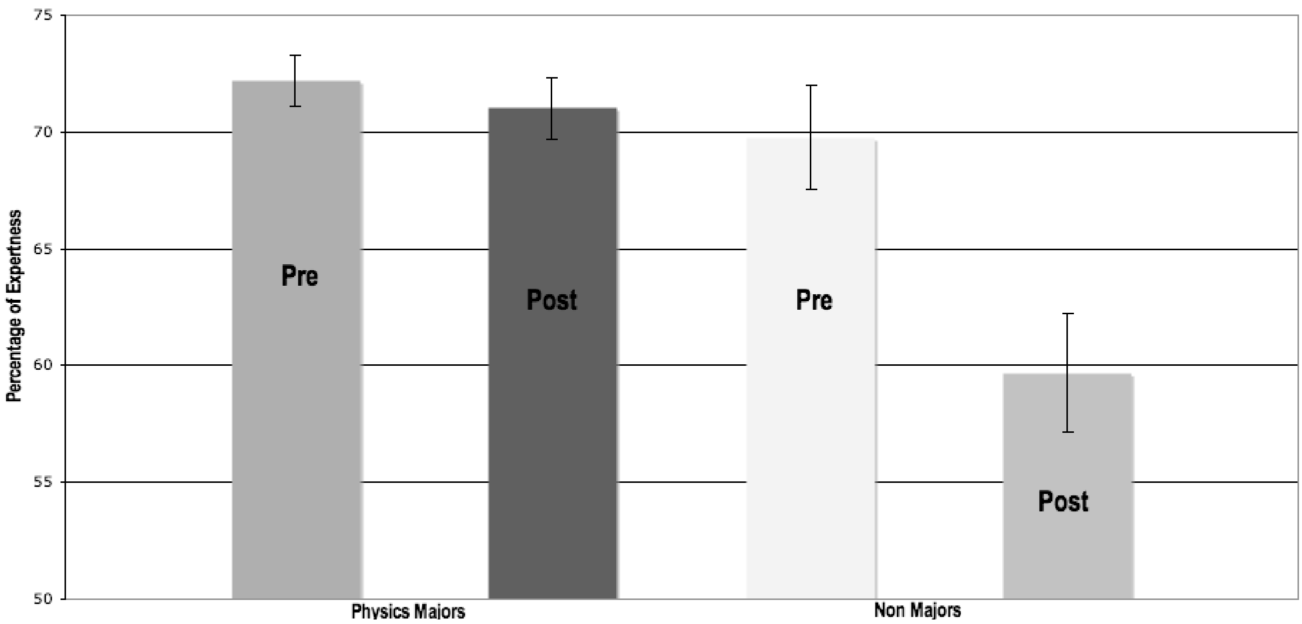

Figure 3: Physics majors and non-majors pre and post instruction

A similar effect was seen in the male-female split, with female students becoming less expert after instruction, although this effect was less pronounced.

CLASS in Schools
We also undertook the survey with school students in order to look their attitudes and belief. There have been no previous studies in this area thus there were no preconceived ideas as to what the results would show. All students surveyed were studying Higher or Advanced Higher physics at secondary schools across Scotland. Again a mixture of students intending to study physics at university and those who were not were surveyed.

Due to the difficulty of getting access to students to complete the survey and the time scales of the project it has not possible to carry out a pre and post teaching surveys. 170 students were surveyed once, in the months before their school leaving examinations. The results are currently being analysed.

Expanding on previous research we have looked in greater detail at the make up of the class and how specific groups are affected by the transition. We have seen that non-majors and female students show a drop in their levels of expert like thinking after a year of instruction.

The only areas where students' beliefs are not seen to decline are areas that have been specifically targeted by the course at Edinburgh. This leads to the question of whether we should be designing courses specifically to target these areas or is this part of the natural process of adjustment to university life and study. In an attempt to answer these question the project will be extended next year to poll final year student to gauge their levels of expert-like thinking.

Attitudes and beliefs are critical in determining a student's approach to learning a subjects however these are often overlooked in favour of grades when trying to predict the future success of students. Supporting the transition from tertiary to secondary education comes from being aware of these issues and, potentially, taking steps to address them in introductory level courses.

Retention is a large problem for the sciences with students leaving courses throughout their degree. Many of those who do choose to leave find themselves feeling disillusioned with the courses, claiming it is not what they expected from school. Being able to identify where these drops in attitudes and beliefs lie means that they can be targeted, leading to more confident students and in the long term to greater retention of student numbers.

Acknowledgements
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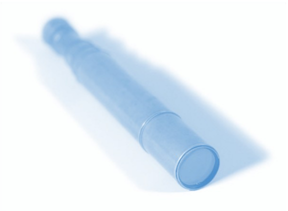

What is effective learning in science? Impact and outcome from a CETL

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Abstract
What is it like to have HEFCE funding and the opportunity to spend it developing good practice in the learning and teaching of science for both higher education and school sectors? In this article we describe how CETL funding at CELS is being used to develop staff, engage students and promote interest in science amongst over 21,000 young people in the East Midlands. We report on how staff were enabled to develop new resources for the teaching of science from undergraduate to Masters level as well as pioneering innovative outreach activities for schools (for students from 5 years old upwards) through our innovative sabbatical scheme for staff - which also supported early career academics in gaining full lecturing posts. CELS' projects cover a wide range of science - both the traditional and interdisciplinary. Examples include work on troublesome knowledge in chemistry, forensic science and physics, new approaches to assessment, e-learning materials for protein purification and biochemistry, new experiments in green chemistry, physics for forensics and astronomy projects for schools. However, this is also a story of pushing boundaries where effective collaborations across subject and institutional boundaries allowed new developments in outreach e.g. at the science-art interface which led to critically acclaimed theatre productions on science.

...a story of pushing boundaries where effective collaborations across subject and institutional boundaries allowed new developments in outreach

Introducing CELS - a CETL
The Centre for Effective Learning in Science (CELS) at Nottingham Trent University is a HEFCE funded Centre for Excellence in Teaching & Learning – a CETL. What are CETLs and why did HEFCE invest over £300 million in them? HEFCE said:

> *We envisage that CETLs will sustain and stimulate further excellent practice through teaching that is informed by scholarly reflection, developed through innovative and adventurous thinking, extended to learning in new contexts, and (reach a wider audience) through active dissemination of good practice'.* (HEFCE Invitation to Bid 2004/05, paragraph 16)

In this review I will demonstrate how we are seeking to convert that vision into reality.

CELS is one of 74 CETLs and one of six with a specific science focus. We cover both traditional core sciences (biology, chemistry & physics) as well as the newer interdisciplinary sciences (forensic and sports science). CELS aims to:

- teach science in HE more effectively and
- inspire the next generation of scientists

Our spectrum of CETL activities includes developing forms of teaching (online learning); ways of conceptualising and supporting student learning (practical work, simulations); influencing the curriculum through work placements in schools; improving assessment; and effectively encouraging young people to aspire to Higher Education.

Investing in people
Staff are both the major resource and cost in higher education. First and foremost, our HEFCE funding was therefore an opportunity to invest in people – staff, students and the wider community - allowing them to develop their ideas and potential. How did we do this?

a) Developing staff - the TIPS TOPS scheme
For academic staff the CELS sabbatical scheme was created. It is based on secondment of academic staff for up to one year, usually on a part-time basis, (similar to a 'research sabbatical' model). Seconded staff carry out projects in one of two areas - either with the Team for Integrative Projects in Science (TIPS) or the Team for Outreach

Projects (TOPS). The role of TIPS TOPS is to deliver the key CELS objectives as well as local learning and teaching strategies. Topics undertaken cover all subject areas in the School of Science & Technology.

The TIPS TOPS scheme also seeks to help staff obtain maximum benefits from their sabbaticals e.g. in collecting evidence for claims for promotion under university reward and recognition policies. Accordingly, TIPS TOPS staff are supported by a programme of activities to help them develop their approach to scholarship and reflective practice. One objective of this support was to enhance staff engagement with evaluation of their projects as well as active dissemination of their outcomes. HEFCE requires robust evaluation and dissemination strategies from all its CETLs .

An emerging theme is that staff, who are expert researchers in their own field, may be uncertain of how to publish in science education. We offer support by building in action learning sets and staged internal dissemination activities as well as opportunities to attend development events, present at conferences and write papers. Evaluation of the TIPS TOPS scheme itself, over the three years it has operated, shows that whilst there is room for improvement, colleagues did attach most value to having time and space to reflect on their teaching and to develop their perceptions of student learning. We are currently engaged on a comparative research study of how this model of staff development compares to other schemes operating in the university[1].

Investigating how science concepts are understood, or misunderstood, is one of our key areas of investigation at CELS and has involved student focus groups, questionnaires and diagnostic testing...

One observation from this and other experiences of evaluating science education projects, is that many proposed evaluation strategies are superficial and limited to a version of a 'happy sheet' e.g. "Evaluation will be via an electronic satisfaction questionnaire for the 1st cohort". However, the challenge for science education projects is to go beyond this and look instead at what measurable impacts there have been on learning or on other staff - i.e. getting people to consider questions such as "How will you know if you've been successful at improving learning?" "What baseline data do you need to gather before you start your project?" "What is an appropriate methodology?" Areas to consider can include improved assessment scores and changes in student learning practices.(See also section on effective learning below.)

b) CELS lecturers - career development and cover for TIPS TOPS

Frequently staff awarded a teaching and learning development project are expected to 'buy themselves out of teaching'. This presents practical issues such as identifying someone to cover teaching. Such approaches do not usually support relief from associated assessment and administrative demands. To address these sorts of issues, we created fixed term three year appointments - the *CELS Lectureships*- as career development posts for aspiring lecturers. Our seven CELS lecturers undertake a full spectrum of lecturing duties, administrative duties, gain a full range of teaching experiences as well as joining an existing research team. They are offered places on the HEA accredited PGCertHE programme for new university lecturing staff. Going beyond providing cover for colleagues to undertake sabbaticals, CELS lecturers have themselves been innovative teachers - with contributions including new teaching resources and new activities to support outreach work, e.g. a Forensic Microbiology master class. This work contributed to a recent article on Bioscience Outreach at NTU for *Microbiology Today*[2]. The validity of approach as career development was demonstrated when two CELS lecturers successfully achieved full time lecturing positions after a full competitive appointment processes.

c) Students

We set out to improve the quality of the student learning experience by delivering more effective and innovative teaching materials and approaches, enhancing student employability and creating new learning environments through our new facilities. Much of this work has been through TIPS TOPS projects, other developments include:

Enhancing Student Employability

A credit-rated, school-based, work experience placement (based on the successful national *Undergraduate Ambassadors Scheme* (*UAS*), see web links) was validated as a Level 3, 20 credit point option module on a number undergraduate programmes in science and technology. *Communicating Science and Technology* module was warmly welcomed by student representatives when it was introduced, [NB *UAS* scheme was new to NTU]. The module had grown from 8 students in its first year to 20 students in 2008-9. Several students have since trained as teachers. Students are trained, CRB checked and placed in a school for twelve half-days. The idea is to improve the science experience of school pupils. Students taking the module state that the experience has improved their communication and presentation skills, their confidence and time management skills.

Student projects

We feel that it is important to engage students themselves with the research informed teaching agenda by carrying out research into learning. Projects have included designing, developing, delivering and evaluating resources for schools such as "A Forensic *Kit in a Kase* for Key Stage 3"; "A GCSE biology revision web site"; "A Forensic Science web site for Key Stage 4"; "PowerPoint revision resources with Flash animations for KS4 science"; and "Revision guides for new A2 chemistry programmes". They have also looked at learning issues in HE e.g. “investigating knowledge gaps and designing flexible learning materials for first year chemists”.

What do we mean by effective and can we measure it?
Having labelled ourselves as a Centre for Effective Learning one question to be asked is how do we know if we are ‘effective’? Working with specialists and an external evaluator we evaluate at all levels - from individuals and a self-reflective approach through to an independent, external evaluator. Themes for evaluation have included:

- How successful are we at raising aspirations and how do we measure this?
- What is the quality of the student learning experience?
- What has the impact been on staff?
- Has the CETL affected a change on the university’s systems and processes?
- Are the developments and lessons learned transferable across the sector?

Evaluation in these terms could be seen merely as ‘jumping through hoops’. However, when meeting colleagues a common challenge is “Given all the money you’ve had - what impact are you having?” So what is impact when applied to CETLs?

Starting with dictionary and scientific definitions of impact [3,4] reveals the following:

> ‘*The strong effect exerted by one person or thing on another’;*
> or
> *‘A force, also known as impulsive force, which acts only during a short time interval but which is sufficiently large to cause an appreciable change in the momentum of the system on which it acts.’*

Wainwright’s review[5] of models and approaches (arising from studies in the social and voluntary sector) outlines some key concepts relating to impact measurement which offer some very useful pointers. In *Measuring Impact: A Guide to Resources* Wainwright [5] states:

> *Impact is a widely used but rarely defined term in evaluation literature. Everyone wants to know how to measure their organisation’s impact but without knowing quite what they mean by the term*

Using Wainwright’s approach it appears that what many people are actually referring to when talking about *Impact* are instead the more easily obtained metrics Wainwright defines as *activities, outputs* and/or *outcomes* (Table 1).

Examples of what Wainwright defines by each of these terms is given below:

Inputs are the resources that contribute to a programme or activity, including income, staff, volunteers and equipment.
Activities are what an organisation does with its inputs in order to achieve its mission.
Outputs are countable units, and are the direct products of a programme or organisation’s activities. They could be classes taught, training courses delivered or people attending workshops. In themselves they are not the objectives of the organisation.
Outcomes are the benefits or changes for intended beneficiaries. They tend to be less tangible and therefore less countable than outputs. Outcomes are usually planned and are therefore set out in an organisation’s objectives.
Impact is all changes resulting from an activity, project or organisation. It includes intended as well as unintended, negative as well as positive, and long-term as well as short-term effects.

Concept	Definition	Examples in a CETL context
Inputs	Resources invested in the CETL	income, staff and equipment
Activities	What we do with our inputs to achieve our goals	training, research projects, learning developments, building learning spaces
Outputs	Tangible/countable products of a CETL’s activities	sessions held, papers written, space utilised, promotion schemes, student learning interactions
Outcomes	Benefits/ changes to people from the activity. Usually longer term and based on CETL objectives	improved student learning, raising achievement, staff promotions, institutional change
Impact	All change resulting from a CETL- includes: intended and unintended effects; negative and& positive; long-term and short-term effects	regional partnerships, interdisciplinary projects, sustainability and embedding of core ideals

Table 1: Impact measures for CETLs adapted from Wainwright

I have interpreted the above definitions to fit the CETL initiative, noting that *Outputs* are about *effort* whilst *Impact* is about *change*. The results are shown in Table 1, which has formed the basis of workshops on Impact for the CETL community[6]. It is worth considering such concepts for any educational project.

Alternatively Boyd's approach in the New Economics Foundation (*nef*) publication *Measuring Social Impact* [7], defines impact as

Impact = (Outcomes) – (an estimate of what would have happened anyway)

Boyd states that

> *Outputs are the direct result of your business objective or programme goal. So for example, 25 people learned new computer skills as a result of a training programme. An outcome is a change that has occurred over the longer term....So perhaps 2 of 20 programmers would have found jobs on their own. That means that the impact of the training programme should be calculated based on the other 18 (people) that started work*

This gives us a sense of value added from our work at CELS –in a given year 6 people would have teaching sabbaticals at the university, with CELS 20 people have had teaching sabbaticals – so according to Boyd, one measure of our outputs are the 14 extra sabbaticals, whilst measure of outcomes and hence impact would be longer term embedded changes in practice such as adoption of e-learning, engagement with outreach or successful promotions.

Investing in innovative learning

a) TIPS TOPS projects

Some examples of themes and project areas are given below:

- *Context-Based Learning - e.g.* Forensic Skills Development in Criminalistics Practical Work*;*
- *E-learning projects – e.g.* Masters modules in Molecular Biology, e-learning resources for Protein Purification; Genomic and post-genomic investigation of micro-organisms;
- *New approaches to practical work* – e.g. Year 1 organic practicals with pre-labs*;* Learning materials to support practical skills in biological sciences
- *Assessment* – e.g. Assessment of large groups; Use of automated assignment marking systems in grading essays;
- *Outreach* - e.g. 'Physics for Forensics' Outreach Competition; Promoting and Developing Green Chemistry for schools and teachers and Ronnie the Skateboarder (Year 9 physics);
- *Supporting student learning* – e.g. Student Ambassador & Mentoring Scheme; A New Approach to teaching Programming

b) Investigating misconceptions

Investigating how science concepts are understood, or misunderstood, is one of our key areas of investigation at CELS and has involved student focus groups, questionnaires and diagnostic testing, carried out with first year students in chemistry, physics, forensic science and sport. Initial findings of this work and its overview of areas such as *Threshold Concepts* and *Troublesome Knowledge* were presented at the Science Learning and Teaching Conference and Variety in Chemistry Education in 2007[8].

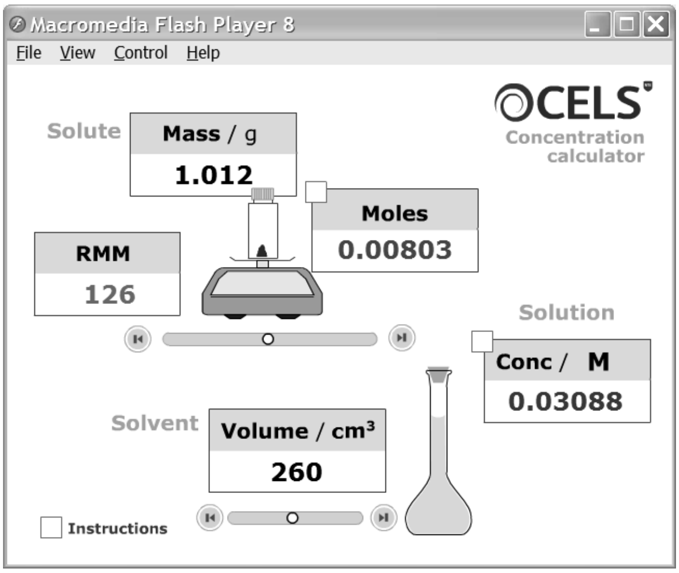

Figure 1: The Mole Calculator

c) Interactive learning materials

One of our keys objectives is innovation in the teaching of scientific concepts, developing a selection of re-usable learning objects for different age groups. Resources include worksheets, presentations and interactive animations, which present scientific concepts in novel and highly visual formats. These were designed by members of CELS team. They range from interactive flash tools for undergraduates - the mole calculator (Figure 1) and dilution factor tool, to 'gravity balls' for primary schools. There is a 'molecular geometry' resource for students to support those with diverse entry profiles. There are also examples of teacher's tools and worksheets to help in production of lesson starter/closer activities.

The curriculum focused materials are available for use in the classroom or for independent study at home and are available via the CELS website. Is your area of learning crying out for an interactive tool? Get in touch and we'll see what is possible.

d) Electronic voting systems (EVS)

The use of EVS was piloted in CELS during 2007, having been introduced to their potential by Simon Bates[9]. This led to a lot of interest in their use for formative assessment and checking conceptual understanding. We have since used EVS to look at threshold concept with first year physics students, in addition to using them widely in outreach activities with school children from 5 years old upwards. This happened in parallel with the study by Niyadurpola and Read[10]. We note, as they did, that EVS offer anonymity to the voter and so encourage participation in quizzes and evaluation. EVS also attracted much interest from European colleagues at sessions on the work of CELS [11].

Investing in raising aspirations - innovation in Outreach
Fifty percent of our activity is Outreach based. When CELS started 'footfalls' of young people were around 2500 per year for science based activities, (mostly in chemistry) of which 1200 came from one big primary event. Since autumn 2005, we have significantly diversified both type and subject coverage of activity. Average footfalls annually are now around 5000 per annum and so far over 21,000 young people have experienced challenging and exciting science activities since CELS began its operations. Our evaluations show that an impact on learning and aspirations:

> *'Thanks to your contribution the students now have a renewed sense of not only the career opportunities throughout the science industry, but also that science moves outside the classroom' (Charlie Astbury, Northamptonshire Education Business Link Organisation)*

Examples of types of outreach activity developed include: Activity Days; Competitions; Guest lecturers; Teacher CPD; Workshops; Master classes; Careers events; Kit in a Kase and Demonstration lectures. To see these in action visit our picture gallery on the outreach section of our website.

However, it's not just footfalls that matter, but the effectiveness of the learning experience. We have turned from large scale events with 500 pupils per day – where the extent of learning taking place was difficult to measure – to workshop based activities with smaller groups and adding teacher CPD activities.

> *'Not only do the schools appreciate the ability of the CELS team to go out into schools to deliver a varied menu of sessions but value the opportunity for them to take their children to a building like CELS on a University Campus and be able to see, handle and experience fully functioning laboratories. Such an introduction to the world of Science and University life at such an early age is bound to have an influence on the lives of some of our young people that will remain with them for a long time and maybe influence their career path and/or their desire to actually go to university later in life.'* (Alan Carr, Manager of Education Improvement Partnership.)

a) Innovative Outreach through Kit in a Kase - activities in the classroom
CELS has piloted and developed new approaches to Outreach. The most successful of which is *Kit in a Kase,* a concept that was developed since the receipt of funding. These curriculum-focused, classroom-delivered activities involve presentations and hands-on practical activities, many of which are enquiry-based. Through working with Dr Sam Tang, from the University of Nottingham, we gained experience of her primary focused *Oil spill* activity which we co-delivered to regional audiences. This activity encouraged CELS staff to develop further activities for wider age groups, which we call *Kit-in-a-Kase*. Kits now range from early years infants - *Materials Kit* (KS1) and *The Body* (early KS2) to *Bricks Bananas & You (DNA*) and *Colour Chemistry*. They have been delivered by a wide range of people - CELS staff, *Students in Classrooms* students, undergraduate and postgraduate student volunteers. Details are on the CELS web site and have been presented at a number of conferences [12].

The overall *Kit in a Kase* scheme has proved so popular with schools that we are invited back to a school on many occasions. Teacher evaluations state:

> *'Links with real life are extremely valuable.' 'Explanation & visual representation of a complex concept - how DNA relates to cells & Biology.' 'Allowed kids to see role models & ask questions one to one.' 'Whole session was excellent, Kids really enjoyed it – well organised and resourced.' 'Highly relevant to syllabus - Yr6 SATS is tough but this made physics element fun.' 'Facts in talk useful - show how chemistry is used in nature and history etc'*

b) Teacher CPD
Many schools struggle to allow staff to attend off-site training, so CELS has developed another way to offer CPD. Competition events, where schools bring teams of 4 pupils and a teacher, allow us to offer teacher CPD sessions, whilst their pupils are competing. These sessions include showcasing materials, updates on the latest HE research and equipment, as well demonstrations and activities that can be done in the classrooms.

In addition, CELS is working with the School of Education to provide additional opportunities for student teachers to develop their skills. There are sessions on advancing ICT skills, using data-logging equipment and interactive whiteboards. Student teachers have also attended interactive lectures from CELS on exciting and interesting experiments; these are based on the Royal Society of Chemistry (RSC) report "Surely That's Banned!?!" CELS has also worked with the Royal Statistical Society Centre for Statistical Education (RSSCSE) on their *Experiments At* School website and helping to run workshops for mathematics Enhanced Post Graduate Certificate of Education (EPGCE) students. [NB these are students on two year teacher training programmes funded by the government (TDA) with the first year involves Subject Knowledge Enhancement in key areas such as chemistry, physics, maths and modern languages.]

Investing in learning spaces
a) The CELS building
CETL funding brought with it significant capital funding (up to £2.35million) which at NTU we used to co-construct a new building which houses the core of a science education development centre, alongside modern research labs. The CELS area consists of space designed by us to support the delivery of our key aims with a lecture theatre, 3 seminar rooms , an IT suite, a school lab (allow development and delivery of practical activities to under 16s), office space for CELS team and seconded staff, meeting and exhibition space. These flexible modern facilities are seen as having a very positive impact on the wider community both internally and externally. CELS is used extensively for external facing events with schools, small scale HE conferences (e.g. events organised with the Physical Sciences Subject Centre) and professional bodies. There was very positive feedback from prospective students on University Open Days. It has extended the range of learning experiences with final year shows, poster shows, demonstration lectures, seminars, IT sessions and student society events.

Figure 2 Pictures from Icarus and Cosmos productions

b) The Trent Observatory
One of our star achievements was being able to build and equip an observatory with 0.5 m telescope to support undergraduate programmes and provide opportunities for schools and members of the local community to learn more about the science of astronomy. Our monthly Open Dome Events are open to staff and the general public, with talks on interesting, recent and sometimes surprising topics relating to astronomy with opportunities to observe. We have developed a range of undergraduate projects and school based outreach projects that aim to introduce and encourage understanding of astronomy. Successful projects include: *Distances in astronomy; Stars and their spectra*; *Meteors and craters;* and *Solar prominences and scale*.

A very exciting innovation is a project on *Archeoastronomy* (what people in history understood about the stars and the part they played in their culture) with gifted and talented pupils at a local school. The students presented their work to the Joint European and National Astronomy Meeting (JENAM), as part of the European week of Astronomy and Space Science and International Year of Astronomy 2009 in April 2009. The project is led by astronomer and observatory officer Daniel Brown. The pupils had a great time, you can see their report at Astronomy Now! and on the CBBC's *Newsround site* [13] .

Investing in Innovation and Creativity
CETL funding has opened up opportunities to step outside our comfort zone and work proactively across the University. For example, we have worked with a resident theatre company Dragon Breath (see website) in creating *ICARUS* - an art and science performance event, aimed at engaging young people with the critical, moral and ethical issues of biomedical research. *ICARUS* takes the ancient Greek myth of Icarus and weaves it with a modern story about a research scientist desperate to save the life of her daughter who has a degenerative disease. Performed as part of the University's celebration of National Science and Engineering Week in March 2007, it involved a top team of professional theatre makers, working alongside undergraduates on theatre design programmes including puppeteers, designers and makers. Over two years professional artists, students, school pupils, teachers, CELS and scientists researched and developed the performance, which sold out to schools across the region. ICARUS was shortlisted for a THES award in Excellence and Innovation in the Arts. (Figure 2)

Building on this successful partnership our second project is *COSMOS* – following the story of a young girl who needs to travel through the solar system to retrieve her 'story star' after it disappears. On the way she meets all the planets, personified to display their characteristics, before eventually finding her dying star. Coinciding with the International Year of Astronomy and National Science and Engineering Week 2009, it was performed to four to seven-year-olds this March and May and is the result of 18 months' research and development by artists, scientists, teachers, students and pupils. These performances are participatory using storytelling, dance, puppetry, music and digital arts to introduce youngsters to some of the biggest scientific questions.

> *The children will be learning about the structure of our solar system, including distances and relations of size, as well as the life and death cycle of a star. Many of these children will be going to school for the first time, so the performance is also about them encountering new experiences and challenges and taking their place in the world. Another important idea is to show youngsters the importance of engaging with and helping others." Peter Rumney, Senior Lecturer in Theatre Design at NTU, Artistic Director, Dragon Breath Theatre.*

CELS role has included helping theatre students understand the science behind the production, engaging fellow scientists, and supplying science advice as well as sponsoring resource packs for schools to follow-up on the science involved in the production.

Working Collaboratively
There has been a high degree of engagement of CELS with networks and local, regional and national initiatives. This has been one of the strengths of CELS -working in partnership has enabled us to achieve a wider variety of activity. The range of partnerships and collaborators can be found on the CELS web site and includes professional bodies, STEMPOINT, Aimhigher etc. We have also built links with Schools in the Midlands region through active involvement in local initiatives, eg Nottingham Science City and the East Midlands STEM partnership.

Collaboration in outreach work has been a major characteristic of the CELS approach, demonstrated at two national CELS events on this theme *Outreach in Collaboration* (October 2006) and *Outreach in Collaboration II* (September 2008) (figure 3) .


Figure 3: Outreach in Collaboration Conference, CELS September 2008

Other examples of collaborative working and dissemination are:

- Partnership of CELS with the HEA Subject Centres – with whom we have organised events, sponsored conferences, disseminated newsletters and support our CELS Advisory Group;
- East Midlands CETL network - joint events and outreach sessions.
- *Chemistry for our Future*- a multi-university curriculum development project[14] and *Chemistry the Next Generation* events
- *Stimulating Physics* – hosting a Physics teacher fellow and their research project[15].
- European partnerships – EUSCEA – contributing to science weeks & festivals in Norway, Portugal and Italy as well as European funding.

Finally...
CELS has been characterised by its experimental nature. It's a tale of how scientists, educators and their students are being given time and space to implement HEFCE's vision that CETLs be innovative and adventurous in its approaches to learning and teaching. Through working in new areas in different ways with a very diverse group of people, we have learnt a lot about what works and what doesn't and we hope that by sharing these lessons with other members of the science higher education community that everyone will benefit.

If you would like to know more about any of our projects or approaches, then please get in touch or visit our website.

Acknowledgements:
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Web Links

CELS
<www.ntu.ac.uk/cels>
Kit-in-a-Kase
<www.ntu.ac.uk/cels/outreach/Kits/index.html>
The Trent Observatory
<www.ntu.ac.uk/cels/outreach/Optical_observatory/index.html>
Dragon Breath Theatre company
<www.dragonbreaththeatre.com/>
Science City, Nottingham
<www.science-city.co.uk/>
East Midlands STEM partnership
<www.emstempartnership.org.uk/>
European Science Events Association (EUSCEA)
<www.euscea.org>
Undergraduate Ambassadors Scheme (UAS)
<www.uas.ac.uk>

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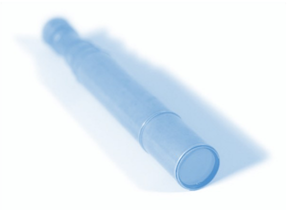

Reflections on a first time experience of problem-based learning

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Abstract
The aim of this paper is to share the author's experience of Problem-Based Learning (PBL). The paper also discuss some of the author's opinions and views about PBL and highlight some of the problems faced by the author as a facilitator as well as point out some of the problems faced by the students.

Introduction
Problem-based learning (PBL) is a total paradigm shift in teaching and learning when all learning is built around real-world problem scenarios. PBL is the richest learning environment that I have encountered. As an academic visitor at Leicester University I had the opportunity to observe during the facilitation sessions and the expert sessions for the undergraduate interdisciplinary science courses. These observations have helped me gained a better understanding of the role of teachers as facilitators in the PBL classrooms and also provided me with greater insights into what problem-based learning is all about. In Leicester the learning environment is based around problem-based learning (PBL) and integrates theory, computing and practical work with class and tutorial activities in a learning community. A restructured state-of –the art laboratory has been designed and built as a dedicated PBL facility and provides a unique space for teaching for group and individual study. Also there are laboratories for hands on experiments in for example physics, earth science, chemistry etc.[1, 2].

Problem-based learning (PBL) is an educational approach that challenges students to "learn to learn" [3, 4]. Students work cooperatively in groups to seek solutions to real world problems and more importantly, to develop skills to become self-directed learners. Here, the goal of problem-based learning is viewed as learning for capability to acquire knowledge rather than learning for the sake of acquiring the knowledge. PBL is unique in its integral emphasis on core content along with problem solving[5]. Within the context of reading in a problem based learning classroom, learning thus become much more than the process of mere seeking of knowledge. Students develop critical thinking abilities by constantly relating what they read to what they want to do with the information. They question the writer's assumptions and analyse information presented, all within the context of finding answers to "What can I do with this information that I obtain?" and "What does understanding this information mean to me?" This article discusses some of the challenges in learning that students face and also presents the author's view about some of the problems that teachers face in a problem-based learning classroom. These views are based on the author's personnel reflections from class observations with some of the points and views drawn from the author's experience with the Solar Cells PBL (Appendix 1) which was conducted with the first year undergraduate students at the University of Leicester.

Opportunities for combining conceptual understanding of physics with critical thinking skills occur when the students encounter the real-world applications. Whenever possible, problems and experiments relate the basic physics principles to the real world. Students who acquire scientific knowledge in the context in which it will be used are more likely to retain what they learn and apply that knowledge appropriately[6, 7]. The Solar Cells PBL is a first year laboratory project which was designed so that students will gain some understanding about the physics of the solar cells. Students were given with the trigger question, the suggested references and the list of equipments (Appendix 1).

PBL requires students to take on active learning strategies and adopt a self-directed learning disposition. Some students find it difficult to cope when asked to transform into active critical thinkers. PBL teachers may also face difficulty as they prepare to facilitate discussion, provide coaching, challenge student thinking and manage group work[8].

In Leicester the learning environment is based around problem-based learning (PBL) and integrates theory, computing and practical work with class and tutorial activities in a learning community

Some of the challenges for the PBL classrooms are as follows:

Limited experience in group work management
One of the weakness that my students had during the Solar Cell PBL was that they were lacking in awareness of the importance of group work and time management. I noticed that they were not fully conscious of the need to divide the work load and plan to meet together to share their findings, initiate discussion and draw a conclusion. During the laboratory session I witnessed only one student actually trying to do the experiment, while the other three students were just standing by and watching. I had to motivate the group into using most the resources provided on the work bench and also make them realise of the need to manage their time well and to keep focus on how to best achieve the group action plans for the project as a team. As group work is integral to PBL and students need to learn how to make optimal use of their time and resources, I tried to coach my students on how to function effectively in as a team. This involves cultivating skills to know how to organize the work, distribute responsibility, breakup complex tasks, and provide useful feedback on work that is done. As a teacher I felt that I could contribute by helping my students better understand the merits of groupwork.

Initially, I believed that PBL is related specifically to the shift in the role from lecturer to facilitator; in the context of problem-based learning but over time I began to see that it was much more complex than this. What became apparent is that I am to perform and manage increasingly diverse and ambiguous roles. The facilitator's position is one of being there to ensure that the team works effectively and that team member's learning needs are met. However, the facilitator is also there to promote the development of a team culture, to challenge, to help the balancing of task and process and to enable students to move from critical thought and then to critique. The position and type of power and understanding of students' perceptions and concerns are important components in what it means to be effective in the facilitation process[9].

Investment in student preparation and understanding of PBL either during the admission process or prior to admission has proved to be a very valuable component in the successful implementation of the PBL programme[8]. If admission process continually emphasizes the nature of learning and the expectation of group participation, candidates will be made aware of what is expected of them and of any need to adapt. If students enter a PBL programme with insufficient awareness of its nature and of the expectations for their behaviour, it may be difficult to change their behaviours while at the same time expecting students to achieve content mastery[8].

Lack of familiarity with inquiry learning
To start using inquiry, teachers must first be familiar with the conceptual frameworks that structure the subjects they teach and the ground rules that are important to particular disciplines. Questions, whether self-initiated or posted by others, are at the heart of learning by inquiry. While questions are a part of the traditional classroom, the source, the purpose, and the level of questions are quite different. In the traditional classroom, the teacher is frequently the questioner, and the purpose of questions is often to asses whether or not students have learned and absorbed particular information. When the teacher poses questions in an inquiry classroom, the questions are more reflective in nature. Appropriate inquiry techniques are important in an inquiry classroom especially at the initial stages where guided inquiry serves as the base for later, self-initiated questioning.

Inquiry learning requires being prepared mentally and physically for the process. The mental process might be more than a personal philosophical change about teaching and learning. The physical process has more to do with the preparation of the learning environment. The learning environment should be enriched with learning resources that will both stimulate and help answer the learners' inquiries. The internet if made available can be an important source of resource materials and resources for learning. Depending upon the nature of the activity, it might be necessary for the teacher to plan to have supplies and materials available for the students to explore some of their own questions. In addition, to start using inquiry, the teacher had to be prepared to become familiar with various types of questions and students "learn to learn" from them.

For the Solar Cell PBL single crystal silicon solar cells were used for the experiment. The students had access to the library, computer and internet resources. In the beginning the students had problems identifying the learning issues for the project. They were facing difficulties identifying their research direction as well as planning for their group action plans. Students found it difficult to identify the critical issues and to generate a coherent research design. They were often unclear about how they can relate what they were currently reading to what they already knew. They were also unfamiliar with different stages of the inquiry process, such as generating hypothesis, providing logical arguments, applying the correct formula, tabulating results, interpreting data, transforming data into a product. When the students had an appropriate learning context and the need to seek the necessary information, they also saw how things finally "come together". This is an aspect of critical reading that can be promoted within the framework of problem-based learning.

Inadequate feedback on learning assessment
Effective inquiry teachers are constantly assessing students. As they facilitate inquiry learning, they are monitoring the progress of the learner. Learning and assessing learning outcomes go hand-in-hand. Effective teachers are alert to the needs of particular students and the needs of the whole class. If there is an individual need, the teacher will work one-to-one with the student. If the whole class is experiencing a similar problem, the teacher will likely do whole-class mediation of the weakness. The important point is that assessing can dictate important instructional changes.

A one-to-one assessment was used for the Solar Cell PBL students following the end of a laboratory session. While one-on-one assessment is time consuming and laborious, it can be a very effective way to learn what student knows. Individual assessment has revealed my student's perception of the following:

- How the student views his individual effort.
- How well he participated in the group
- The quality of his work
- How satisfied the student is with his work
- Things he found difficult to figure out.

- Things he found interesting and enjoyable
- How he might improve his performance
- How he viewed his work compared to that of an expert
- How his skills, knowledge and habits of mind improved
- What he viewed as important about the project or unit of study

Perhaps one of the best ways to really assess student learning from inquiry learning is through a narrative assessment. This narrative becomes an important report for the student, the family and the teacher. It is very important to see how integrated are the process of inquiry learning and the assessment of inquiry learning. Narrative provides a way for students to demonstrate not only what they know but also how it relates to their other knowledge, their ways of seeing the world, and the ways they assess and analyse ideas.

Assessment, like good teaching is about many things at once: it should encourage interest, commitment and intellectual challenge, enhance student independence and responsibility, make the teacher's expectations unequivocal and show respect for our students as our learning partners[10].

It is extremely important that there be a feedback from students to the teacher regarding the degree to which the learning objectives have been achieved. This feedback enables the teacher to make important changes in teaching and learning strategies. Through this feedback process, teachers begin to realise that all methods of learning are not equally effective. The approach to learning is not "one size fits all," and important modifications can and should be made depending on what each teacher finds helpful with particular students.

Narrative provides a way for students to demonstrate not only what they know but also how it relates to their other knowledge, their ways of seeing the world, and the ways they assess and analyse ideas.

The feedback from the teacher to the learner is very important as well. The learner becomes more informed about what he knows, what skills he has, what conceptual understandings he has, and what nurtured habits of mind he possesses. He knows what specifics he needs to work on in order to achieve success. As he progresses with achieving these attributes, he develops more confidence in his ability to continue to learn. Giving feedback to students is integral to improving student learning. Barron *et al.*[11], suggest that teachers can better guide and monitor projects by incorporating formative self-reflections by students, by creating a classroom culture that supports frequent feedback and assessment, and by finding ways for students to compare their work with others. Teachers can make students take their work seriously by incorporating opportunities that involve external audiences in assessing students' performance. This can take the form of a presentation or seminar.

Scaffolding for PBL Success

During the first meeting with the Solar Cell PBL group, I found out that all four students had no previous knowledge of the physics of solar cells and they had no previous background about solar energy. However they all have expressed great interest to know more about the topic. The students were given the trigger problem (Appendix 1) with the suggested references and they were scheduled to come back the following week to do the project. The following week they came in with a few references they borrowed from the library. I approached them the first week and suggested that they come up with a group action plan for the day. I noticed that they were all very busy reading from the references. The students were given time to sort out what they wish to do and after about one hour and a half I noticed that nobody has yet touched or attempted to look at any of the equipments on the table or even venture to see what a solar cell looks like. They were all busy flipping the books. So I decided to ask if anybody can tell us what is a solar cell ? Have you seen a solar cell before? How is the structure (cross-section) of the solar cell? Can a solar cell be a hundred per cent efficient? I made them aware of the brittle solar cells which were on the table and reminded them to handle the cells with care. One of the students replied, "We have studied about a diode, but not a solar cell." So I suggested that it might be a good idea to find out the difference between a diode and a solar cell. The students did not attempt to make any circuit connections until nearly the end of the first session. I found that posing questions did helped students to "learn to learn." In the beginning I had to remind myself many times of my role as a facilitator in a PBL so as not to reveal direct answers but to be asking more questions to help in the scaffolding process of learning.

In the model of cognitive apprenticeship, developed by Collins *et. al.*[12], scaffolding is described as a means of coaching students to the extent that they can perform intellectual tasks on their own. Success with PBL largely depends on whether students have been sufficiently prepared to take on certain new roles, such as those of inquiry seekers and collaborative team players in the classroom[7]. In a PBL classroom, for example, the teacher gauges the difference between what activities students can do on their own and what they need to learn to do to solve the problem. Then the teacher designs activities which offer just enough of a scaffold for students to overcome this gap of knowledge and skills[13]. Effective scaffolding includes activities that help students develop the right mindset, engage students with the problem, divide activities into manageable tasks, and direct students' attention to essential aspects of the learning goals. I believe that the effectiveness of PBL depends to a large degree on the scaffolding provided by facilitators to students.

Learning to Learn: Cooperative learning skills
In cooperative learning, students work together in small groups on a structured activity. They are individually accountable for their work, and the work of the group as a whole is also assessed. Cooperative groups work face-to-face and learn to work as a team. In small groups, students can share strengths and also develop their weaker skills. They develop their inter personnel skills. They learn to deal with conflict. When cooperative groups are guided by clear objectives, students engage in numerous activities that improve their understanding of the subject explored [14].

In order to create an environment in which cooperative learning can take place, three things are necessary. First, students need to feel comfortable, but also challenged. Second, groups need to be small enough that everyone can contribute. Third, the task the students work together on must be clearly defined. Also, in cooperative learning small groups provide a place where:

- learners actively participate;
- teachers become learners at times, and learners sometimes teach;
- respect is given to every member;
- projects and questions interests and challenge students;
- diversity is celebrated, and all contributions are valued;
- students learn skills for resolving conflicts when they arise;
- members draws upon their past experience and knowledge;
- goals are clearly identified and used as a guide;
- research tools such as internet access are made available;
- Students are invested in their own learning.

Central to the effectiveness of PBL is the ability of students to work together to solve problems[15]. Teachers can encourage more beneficial and meaningful group work by prompting students to pool talents and resources and by guiding them to resolve conflicts while working together. Woods[16] discussed some of these skills.

Learning to Learn: Inquiry Skills
Memorizing facts and information is not the most important skills in today's world. Facts change, and information is readily available. What is needed is an understanding of how to get and make sense of the mass of data. Through the process of inquiry, individuals construct much of their understanding of the natural and human-designed worlds. Inquiry implies a "need or want to know" premise. Inquiry is not so much seeking the right answer, because often there is none, but rather seeking appropriate resolutions to questions and issues. To educators, inquiry implies emphasis on the development of inquiry skills and the nurturing of inquiring attitudes or habits of mind that will enable individuals to continue the quest for knowledge throughout life.

In the Solar Cell PBL, students had to apply the following inquiry skills:

- Investigate the factors that affect the operation of the solar cell.
- Investigate the current-voltage (IV) characteristic of the solar cell. To obtain the IV characteristics the students will have to design a circuit using the equipments listed.
- Investigate the effect of the load resistance (R) on the IV characteristic of the solar cell. Students need to vary the values of the variable resistance and obtain the data for the current (I) and voltage (V) for various resistance (R) values.
- Investigate how to find the short circuit current (I_{sc}), open circuit voltage (V_{oc}) and the maximum power point (P_{max}) for the solar cell. Students need to use the data obtained to plot a graph and identify the V_{oc}, I_{sc} and P_{max} values.
- Determine the fill factor (FF) of the solar cell. Students need to use the graph which they have plotted and the various points they have identified above to calculate the FF and the efficiency (η) of the solar cells. This stage will involve application of the formulas to calculate the fill factor and the efficiency (η) for the solar cells.

$$FF = \frac{V_{mp} I_{mp}}{V_{oc} I_{sc}}$$

$$\eta = \frac{P_o}{P_{in}} = \frac{V_{oc} I_{sc} FF}{P_{in}}$$

- The incident power for standard calculations is usually taken as P_{in} = 1000 Watts per square meter [17].
- Determine the ideal resistance for the solar cell. This stage involved students using the collected data and computing the power (P = IV). By plotting the graph of power (P) versus resistance (R) the students will then identify the ideal resistance which is the value of the resistance that will produce a maximum power on the graph.
- Investigate the effect of light levels on the solar cell. This can be done by using various bulbs and varying the number of bulbs. The experiment can be repeated to study of the effects of light levels on the fill factor and efficiency of the solar cells.
- Investigate the effect of the series and parallel combination of the solar cells on the current voltage characteristics of the solar cell. This involves joining the cells in series and parallel and notifying the changes in the current and voltage outputs.
- Match the combinations of cells that will suit with the application of a solar water fountain.

In PBL, students must seek and evaluate the information they acquire related to the problem they are given to solve. Activities that involve inquiry learning include problem framing, data gathering, divergent thinking or idea generation, evaluating alternatives and applying a solution to the problem[18].

Learning to Learn : Reflection Skills
Reflection skills essentially give students the mental time and space to consider what they have been doing, value it, place it in context and make mature decisions about what to do next. It does not necessarily involve change, although it may lead to development or change.

Reflection involves focussed thinking about learning during the learning process. However, students often get caught up in completing a task and do not take time to reflect. Students learn from two kinds of reflection activities. The first focuses on the content, with students asking questions such as "What do I know now, and how can I use this information to meet the project's goal?" The second is reflection on the learning process, wherein is asked such questions as "How am I doing as a learner in this environment – as a self directed learner, as a problem solver, and as a collaborator? What are my strengths and weaknesses? How can I improve?"

While some mistakenly believe that interrupting the process of learning to reflect is too disruptive, on the contrarily, Kimbell *et. al*.[19], have shown that interrupting the design or problem solving process to reflect actually improves problem solving and thinking processes. For the Solar Cell PBL, reflection activity has been practiced when students have completed a phase of the process. Reflection is linked to monitoring. Since monitoring occurs near the beginning and near the end of a task, using these times to remind students to write down their reflections can be productive.

If PBL changes the game and learning is to be seen as relevant to life, new methods are needed for the teacher to be able to assess student progress.

Learning to Learn: Assessment
The ill-defined problems of PBL do not have answers that can be written in an answer key. It is difficult to develop multiple-choice questions that will measure creativity, critical thinking and teamwork skills. If PBL can meet the demands of the information age, educators will need to replace product-oriented assessment techniques with valid assessments for process-oriented education[3]. Boud and Felletti[7], in their meta analysis, point to the difficulties with testing knowledge as isolated facts out of context. Tchudi and Lafer[20], describe traditional assessment as a game that engages the student in guessing what the teacher wants rather than demonstrating the best they can do. If PBL changes the game and learning is to be seen as relevant to life, new methods are needed for the teacher to be able to assess student progress. The emphasis should be on being able to locate the necessary information to solve the problem rather than memorizing facts[21, 22].

Gallagher *et al*.[23], found that a laboratory notebook, just like scientists use, provided a means to record observations, store data, record proposed hypothesis, and list ideas that need to be recalled for later consideration. This lab notebook is easily expanded into a problem log whose format can be utilised in problems that are less science based. The problem log is a journal that records ideas, plans, strategies, and progress. It provides a written record of a student's train of thought. Specific log assignments can be given to help teachers track the thinking process and document student participation. For the Solar Cell PBL students were required to keep a laboratory log book. Students were also required to submit a project report at the end of the project.

Another potential assessment tool is concept mapping which also aid teachers in identifying errors in student learning [24]. Concept Mapping is also used in curriculum development. As teachers prepared concept maps of curriculum, they were able to improve the hierarchical arrangement of content with increased detail and greater integration of concepts. Concept mapping can not only provide a useful means of assessing knowledge acquisition of the students but it can also aid teachers in developing meaningful ill-structured problems for PBL.

At Leicester, the students of the interdisciplinary science courses are required to keep an individual portfolio containing their research, ideas, notes and results. The software that the students used to create individual portfolio is called "Microsoft OneNote", a component of Microsoft Office which is available on their PC. The portfolio is a collection points for all their research and laboratory work. The student's individual portfolio will be looked at by a member of staff and marked. Students received feedback on their portfolios including suggestions for how to improve. Portfolios take the place of lecture notes and laboratory notes and should build into a useful, personal repository of information. One of the advantages of keeping the portfolio in OneNote is that everything that is put in is linkable, searchable, and filed in logical places.

Student outcomes from an inquiry-learning experience should focus on the following:

i. the development of information-processing and problem-solving skills (from observation and inference to synthesis and evaluation),
ii. the nurturing of habits of mind (from beliefs and opinion to respect for data and demand for verification
iii. applying these attributes to learning content,
iv. making sure the content is learned in a conceptual context of how the natural and human design worlds are organised, interrelate, communicate, and change.

Thus the focus of assessment of inquiry learning should be on the following:

- The degree to which the processing of learning skills has been developed.
- The degree to which the habits of mind of disciplines, have been nurtured

- The degree to which the students have developed the content knowledge set in the context of broad understanding.

One problem in PBL is that while students are constantly encouraged to be engaged in the learning process, assessment of student learning might be inclined to focus instead on the final learning product. PBL teachers need to better understand meaningful ways of assessing student work to motivate learning. Woods[16] clarifies a variety of topics related to assessment for PBL.

The issue of student assessment, and how students are generally assessed in the traditional approach, is a crucial challenge to problem-based learning. In spite of all the good intentions of educators, there is no question that what is tested is the key factor in determining what is taught and learned. In spite of lots of good efforts to the contrary, student assessment, in the final analysis, is heavily oriented towards content mastery, mastery of “what we know.” While this is important, other outcomes of problem based learning include conceptual understandings, skills development, and nurtured habits of mind, things that are difficult to assess by traditional paper-pencil type instruments. Portfolio assessment, which can evaluate learning progress, is one way of assessing the success of problem based learning and skills.

Unless the teacher can pinpoint these missing attributes, it will be very difficult to really help the learner. Tools are not readily available to help with this type of situation, because the focus has been on “what we know” rather than a focus on “how we come to know.”

The appropriate use of new and emerging technologies would appear to offer much assistance in this area of student assessment. Generally, though, schools have not moved very far in using technology to measure skills development or to determine to what degree students have nurtured their own habits of the mind.

Systematic Challenges

There are lots of challenges to attempts to change education from an institution focussed on “what we know” to one focused on “how we come to know.” Many, if not most, of these challenges are systematic in nature. Among the systematic elements in a school/community are: the administrative leadership and support, the instructional resources, the preparation and training of the teachers, the application of new and emerging technologies, the design of facilities and spaces, and the support and involvement of parents. If these elements are not aligned and supportive of inquiry method of learning, then the teacher may have difficulty implementing problem-based learning in the classroom.

Another challenge to PBL might be the attitudes of many parents, community leaders, and educators. Many parents might feel that students should memorize and know content, do lots of homework (even though it might be lacking in relevance), and do well on the tests and examinations. They might also think that focus on skills development is less important. Part of the work of implementing PBL is to make stakeholders aware of its importance.

School administrators might not view a school or a school district as a complex system that needs to be coordinated at every level. As a result, new and worthy goals might be set in the context of a school/community system that might have resisted, and might continue to resist, change. Wonderfully high standards might have been imposed, but teachers might not often be given enough guidance they need, or the techniques of teaching, which are required to ensure that students meet them.

Conclusion

PBL teachers constantly face challenges of encouraging students to go beyond the given information, to reflect on learning, and to actively consider how their knowledge might apply in novel contexts. Students are encouraged to constantly discover and to try new ways of learning. To facilitate these goals, teachers and students need to be provided with the appropriate and accessible pedagogical tools and support. As students develop more self-directed learning strategies, teachers can provide less scaffolding support.

If the focus is to be placed on new ways of learning, teachers cannot be educated in the old ways. Parents must be informed to understand and support PBL. New and emerging technologies must be used to enhance and manage learning. Administrators and community leaders must be develop the necessary support system, and appropriate instructional resources must be made available. All of the important systematic elements must become aligned with the learning outcomes.

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Appendix 1

Solar Cell Experiment Trigger:
Crysalis Toys Ltd has a solar cell that they wish to use in a light powered water fountain. What range of combinations of cells and water fountain parameters would be available to the designers? Would there be any potential applications in micro-irrigation projects?

Suggested References:

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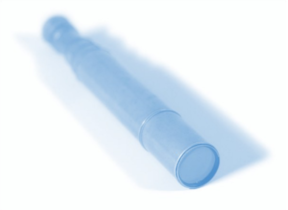
- <www.brillianz.co.uk/data/documents/Lumen.pdf>
- <www.volkerquaschning.de/articles/fundamentals1/index_e.html>

Equipment List:
Solar cells, ammeter, voltmeter, ADC-11 Data Logger and software, lamps and 40W, 60 W light bulbs, connecting wires, electronic circuit-board, decade variable resistance box (0-100kΩ), 1Ω resistor.

Assessment:
All students are required to submit a laboratory report.



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 1st March 2010, to the editor...

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The deadline for full articles is 1st June 2010.

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).

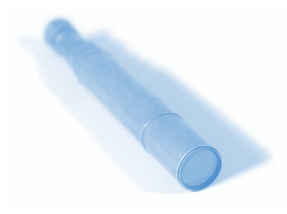
Communications

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 (e.g. 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 - e.g. inline graphics - may be acceptable), with legends. Images will be rendered to grey-scale for printing.

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