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New Directions

in the Teaching of Physical Sciences

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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.

There is a strong outreach theme in this issue with articles covering activities in chemistry and physics, and the effects on all parties involved. Assessment and feedback also feature heavily, with articles on screencasting, delivering audio feedback and designing multiple choice questions (MCQs.) Ever popular topics including undergraduate practical work, transition to university and mathematics support for chemists appear, along with articles on prior knowledge of undergraduates, use of learning outcomes and educational research projects for students.

This is the last issue of New Direction that the Centre will produce; we now hand the baton to the Higher Education Academy <www.heacademy.ac.uk> to produce future issues. We would like to take this opportunity to thank all our contributors and reviewers who have made this publication possible, and we hope that you the reader have found value in what we have offered.

Editor

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Mission to Mars: a one-week introductory project for new physics students

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Abstract
A new event to help smooth the induction of year 1 students to university was run in the Physics Department on a trial basis in the academic year 2009/10 and extended in 2010/11.The event took place in the first week of term with the aim of introducing the students to the Department and the level of engagement expected of them. After some ice-breakers and simple problem-solving, an open-ended physics problem on a topical issue was presented to the students who were organised to work in groups.

In addition to working on the project problem, the students completed some on-line assignments (in order to introduce them to Pearson's Mastering Physics software which the Department has adopted after a successful pilot). In the first year the event ran for 2.5 days, with the groups producing a 1-page report (requiring them to encounter the printing system) and a poster for a poster session. In 2010/11 teams (each containing 5 groups) presented their results to an audience of academics (and fellow students), emphasising the importance of communication skills. The evaluation results indicate that it was a beneficial experience, and the effect of the changes in the second year has been investigated.

The Undergraduate Physics Olympics is a team based event run during the University's Welcome Week encouraging new physics students to get to know one another while doing some fun, competitive physics experiments.

Figure 1: Students taking part in the Undergraduate Physics Olympics

Background
Project-Based Learning was successfully introduced for year 1 students in one module in the academic year 2008/09. The advantages to the students were that they engaged better with the material and in their own words 'had to read the book to be able to answer the questions.' It was decided that it would benefit the students to be required to try (ideally master) independent learning techniques earlier in their university career.

The Undergraduate Physics Olympics is a team based event run during the University's Welcome Week encouraging new physics students to get to know one another while doing some fun, competitive physics experiments (figures 1 and 2)[1].

Figure 2: Students taking part in the Undergraduate Physics Olympics

A more academic introductory project to follow this during the first week of term, immediately after Welcome Week was developed with the following aims:

- To encourage students to realise the level of work expected
- To give students experience of working in a team
- To help students settle into University life quickly
- To enable students to acclimatise to their new environment/learn their way around the Department
- To allow students to meet academic staff in an academic environment
- To help students to get to know fellow physics students
- To require students
    - to organise their computer account
    - to register for Mastering Physics
    - to learn how to obtain printer credit
    - to learn to use a timetable

Method

2009

During the first 2.5 days of term, students were put in teams of 8 and set a project to complete. After introductory sessions to help develop team-working skills and give them a clear idea of what was expected of them, the students were allowed time to work on the project with a member of staff available to offer support and clarify any scientific points. A poster and final report (limited to one page) were due on the Wednesday at 12pm. At the poster session, staff questioned students, and marked their project and responses. Prizes were given for the best poster at a concluding session, which took place immediately afterward. The Project Text was adapted from a Climate Change PBL problem developed at Leicester[2].

Not all politicians agree that CO_2 emissions are responsible for global warming so it is not surprising that they have seized on a recent idea that the observed increase in atmospheric temperature since the start of industrialization tracks the heat dumped into the atmosphere by power stations. How would you brief the minister responsible for carbon reduction?

The project selected was open-ended in order to require the teams to define the problem and set limits on the depth of their investigation. The topic was chosen as something the students would be familiar with, to give this large team (8) of strangers a starting point from which to work. There was a mixed response to the topic of the project, with recent outreach project work highlighting that by AS-level students are somewhat over-familiar with Climate Change. Perhaps due to this over-familiarity some teams chose to take a very surface approach, wasting precious report space discussing politics. Some of the students in these groups listed their reason for not liking the topic of the project as it ‘doesn’t involve physics.’ This was unfortunate and was probably, in part, due to insufficient interaction between staff and certain teams. However 77% of students responded that they enjoyed the experience and found it beneficial, with a further 11% partially agreeing.

2010

Therefore it was decided that the idea of an introductory project is sound, but the topic should be improved. Further, in order to combat students going off-topic and discussing the politics/financial aspect, the project was designed to consist of a number of steps, which cannot be accessed until the previous one is completed. Two students were hired to spend 3 weeks over the summer gathering together and developing suitable research materials for the chosen topic *Mission to Mars.* At this stage the project was divided into five interrelated sub-topics:

- Mission Length and Trajectory,
- Mass Management and Launch,
- Communications and Life Support,
- Radiation and Heat Shielding,
- Landing Craft and Re-entry.

With 120 students working on the project for a week, it was decided to divide them in three groups of 40 both to make it easier to obtain suitable levels of students-staff interaction and to introduce an element of competition with all three groups working on the same project in separate rooms. Within in each

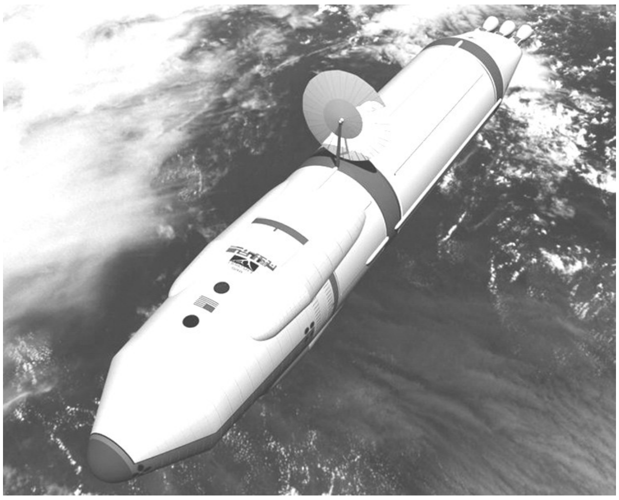

Figure 3: Image from NASA Mission to Mars (www.nasa.gov)

Figure 4: Image from NASA Mission to Mars (www.nasa.gov)

group, the students were further subdivided into 5 teams of 8. In order to introduce the idea of working toward short-term deadlines as part of the longer-term goal, teams were not assigned a sub-topic. Instead each team was given the five possible sub-topics, outlining how, if selected, they would proceed with their research. The proposals were submitted at the end of the day 1 and judged by a panel. Similarly at the end of each session teams were required to submit a 1-page progress report, with an update of their progress and plans.

Each morning and afternoon session started with a flight director meeting in each room to discuss these progress reports, during which, on day 2, teams were informed of their success in winning the right to work on that aspect in their group. Research materials consisted of the NASA Mission to Mars document (figures 3,4) and selected research papers in the room, as well selected websites collected together on a Departmental website for the project. This was to reinforce the importance of using peer-reviewed sources, (not Wikipedia or whatever comes up first in the Google search), which had been emphasised in the introduction section on the first morning.

On the final morning, by which stage the research was expected to be complete, final year students (who had completed an optional module on the topic) delivered a session on communicating science in order to help a group of 40 students develop a coherent presentation for that afternoon. The final presentation took place in a lecture theatre in front of all staff associated with year 1. The groups used prepared materials on flip chart paper, spoke for the set 20 minutes, and to responded well to questions. The winning team were selected by the staff and each given a t-shirt designed for the project (figure 5). All students were also given a mini Mars Bar, which added to the convivial atmosphere as they left on the Friday afternoon.

Figure 5: Design on the t-shirt given to participants

Mastering Physics

As the Pearson online assessment tool Mastering Physics has being introduced throughout the year 1 programme, a session was incorporated to allow the students to register with staff support. Feedback from the pilot phase indicated that students did not automatically complete the introductory assessment available, and then had problems with early credit-bearing assessments with basic actions like submitting their answers in the appropriate format. Therefore students were required to complete a short, relevant, introductory assessment, which they found straight-forward but later beneficial according to feedback. They were also given three Mastering Physics homework assignments (Monday due Wednesday, Wednesday due Friday, and Friday due Monday). The dual aims were to enable them to revise some basic, relevant mathematical and physical concepts (e.g. simple dimensional analysis), and to impress upon them the idea that after working 9am-5pm, they are also required to study/complete work in the evenings.

Evaluation

Seventy-four students completed a bespoke questionnaire. Although only 54% indicated the team topic they worked on was their first choice, 94.5% reported that they were happy with the work done by their team, taking satisfaction in what was achieved, particularly the self-directed learning and freedom to explore potential solutions and manage resources as a group. Comments also mention good communication, working well together and developing skills:

"through lots of extensive research i feel we dismissed lots of unvaluable information and were left with good info"
"Learnt a lot and achieved a lot"

When asked if *Mission to Mars* had helped them settle into university life, 89% of students responded positively, with the negative (8%) comments centring around feeling overwhelmed and lack of guidance at the start, which is not unusual as this is likely their first encounter with PBL:

"developed an idea of how to approach research"
"Increased independence"
"Too much to deal with in first week on top of sorting out bank accounts etc."

More than 50% of students responded positively (>80% if include 'somewhat') to feeling they know their way around the Department, know some academic staff, and have command of the basic logistical aspects of being a student at Liverpool. The Mastering Physics introduction and homeworks were felt to be useful by >75% of students, with the level about right. Students were asked if they had previous experience of working a team, 60% said yes, only 4% said no.

In order to put their responses into perspective, students were also asked if they were surprised by the level of work expected of them. Only 35% were not surprised, indicating that they had expected a lot of work, with 62% surprised by either level or quantity, or in some cases both! Overall 54% of students enjoyed the *Mission to Mars* project a lot, 27% a little, with only 7% indicating that they did not enjoy it at all. All five of these had also indicated that they were surprised by the long hours. In total 34% (25 students) commented on the length of the day in the open responses:

"9-5 in Uni with mastering physics is harsh"

Conclusions

Although it came as a shock to some students, the level and quantity of work expected of them at university was made clear to them in the project. Another aim was to give students experience of working in a team, though 60% of them claim to have 'a lot' of prior experience of teamwork. It was clear in the project and in semester 1 modules where team work is assessed, that most, including many with prior experience, had yet to develop skills appropriate to working in a team, and benefitted from the early experience of team work.

In the development of the week-long project structure, the emphasis in the introduction was placed on the importance of source material and research skills. In doing so, no time was given to developing the students' skills at working together on an open-ended problem, as was done in the previous year. A short time after the current introduction, devoted to the students solving some short open-ended problems as a team, giving them some early success may contribute to giving them the confidence and skills to set the scope of the larger *Mission to Mars.*

Secondary to the social aspect students also enjoyed the subject and the work they were doing. Unsurprisingly the international students found it particularly beneficial.

Students appear to have settled into university life quickly, without the option of 'I didn't know how to print my assignment out' available to them. Mastering Physics registration was smoother than the previous year, and no complaints of insufficient preparation were made when credit-bearing assessments were due.

Students claimed to have found the interaction both with staff and other students beneficial. A direct comparison with previous years is difficult due to changes; the Departmental Student Administrator has been moved to a School role, now with less contact with students, while a central booking system has been introduced which did not locate much of the year 1 timetable in or near the Physics Department. Under the circumstances it is easy to imagine the students having little or no identity as a group, however, they have set up their own study groups for the major modules, making good use of the student notice board in the Department, something recommended but not done in previous years. Further in continuously assessed modules in semester 1, the percentage of students not completing work (1-2%) was significantly lower than in previous years (~10%).

Overall the students enjoyed the experience and can see the benefit of it being run in the future. Secondary to the social aspect students also enjoyed the subject and the work they were doing. Unsurprisingly the international students found it particularly beneficial.

Future Developments

There is debate as to whether to make this a credit-bearing module, in which it would lose some of its flexibility from which it gains much of its strength. However it may encourage the participation of those students with an aversion to working in groups or fear of the unstructured nature of open-ended problems. It is intended that the students will not have any lectures/interruptions from other departments allowing them to concentrate and perhaps not feel as 'overwhelmed' by new material competing for their attention. The *New Physics* integrated approach for year 1 to be introduced in 2011/12 will rely heavily on students working in teams in problem class sessions, which will make the Year 1 Project: *Mission to Mars* even more relevant than it was this year.

The news has provided some topical issues as possible future topics such as *How to cool a nuclear reactor?* or *How to cap an oil well at the bottom of the ocean?*

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Using audio for feedback on assessments: tutor and student experiences

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Abstract
Recently we have been providing individual audio feedback to 1st and 2nd year undergraduate Chemistry students on a variety of assessments (posters, laboratory reports, laboratory diaries) with the aim of providing richer, more detailed and more comprehensible individual feedback than is possible within the same timeframe using written feedback. In this communication, various aspects of the use of audio for feedback are discussed including practical and technical aspects of the recording of audio files whilst viewing and assessing student work, the transmission of these files to individual students, our experiences as tutors of providing audio feedback and the experiences and views of students on audio feedback.

Introduction
Evidence from the National Student Survey[1] continues to suggest students are not satisfied with their experiences of assessment and feedback in UK HE. Specifically, in terms of feedback on assessments, the timeliness (*Feedback on my work has been prompt*), level of detail (*I have received detailed comments on my work*) and comprehension (*Feedback on my work has helped me clarify things I did not understand*) of feedback attracts consistently low scores. The prevalence, accessibility and affordability of digital technologies (digital audio, screencasting, webcams etc.) offer new opportunities and possibilities in teaching and learning[2] and specifically in the enhancement of the level of detail and comprehension of the feedback possible through the rich palette of the voice and the shorter time taken to speak comments compared with the time taken to write them[3-6].

Evidence from the National Student Survey continues to suggest students are not satisfied with their experiences of assessment and feedback in UK HE...

The use of audio for feedback and recognition of its potential merits is, however, not new[3], but prior to the digital age it was not widely adopted, at least in part because of the practical difficulties associated with the technology of the time. Although still relatively uncommon at the time of writing, it is evident that the use of audio for feedback is increasing in UK HE[2-6] and it is emerging as an attractive and convenient alternative to handwritten or typed feedback on assessments. In comparison with handwritten/typed feedback, digital audio offers tutors an accessible and convenient means for providing richer, more detailed and more comprehensible feedback to students on their work without it taking more tutor time (and perhaps saving time). Nuances can be conveyed through tone of voice and use of language that would simply take too much time to achieve in written feedback. Specifically, in comparison with handwritten feedback, legibility is not an issue. With today's heavy workloads and considerable time pressures, it is also far more tempting to curtail detail in written feedback to students than is the case with recorded spoken feedback. This communication recounts some of our experiences of providing audio feedback on various undergraduate assessments in chemistry as well as the students' experiences of receiving feedback via audio.

General Technical Aspects
Initial trialling of audio feedback employed a laptop with an internal microphone and freely available software[7, 8] enabling the production of mp3 files. However, this was rapidly succeeded by the use of hand-held digital mp3 recorders (with or without clip-on microphones) equipped with retractable USB ports and costing ~£50. Filenames included the student's name (and sometimes the actual piece of work where this varied between students in the same class). A clear structure to the audio feedback is useful and a prompt sheet may be helpful in this regard. File sizes were typically 1.3 MB per minute, although it is possible to reduce this. Audio files (mp3) were typically 5-6 minutes in duration and were returned to students individually via the VLE (WebCT) using a dummy 'assignment'.

Audio Feedback on Laboratory Diaries

Systematic assessment of laboratory diaries is common to most Chemistry modules at Keele and students are guided to include page numbers and to maintain a contents page from the very beginning of the degree programme, which facilitates the provision of feedback (written/typed or audio). Our first use of audio for feedback on laboratory diaries was in March 2010 in a 15-credit 2nd year physical chemistry module (~36 students) involving practicals on electrolyte solutions and equilibrium electrochemistry, for which the laboratory diary comprised 15% of the module mark. Laboratory diaries were submitted mid-semester and returned with feedback and marks within 2 weeks. We have also recently provided (December 2010) audio feedback on laboratory diaries for ~100 1st year students on a general chemistry module, but the main focus of what follows is on the 2nd year laboratory diaries.

Practical Aspects

The provision of audio feedback on laboratory diaries was relatively straightforward to implement. The general procedure adopted was to read the diary and highlight areas for comment using a highlighter pen (short comments/words (e.g. '*units*') were occasionally added as prompts for the subsequent audio feedback). In recording the feedback, each audio file included an introductory guidance comment to the student similar to the following:

> *'This is the feedback on your lab diary for CHE-XXXXX. I've highlighted specific points in your lab diary to which my comments refer, so you will find it more useful if you listen to this feedback with your lab diary in front of you'.*

Following some introductory general feedback, the student is directed towards each specific section/area for feedback by referring to the page numbers and the highlighted sections/ areas. The conclusion of the audio file included a short summing up followed by the marks for the various assessed components of the diary and the overall mark.

Student Feedback

Of the 36 students 2nd year students who received audio feedback on their laboratory diaries 21 (58%) completed a questionnaire (see Figure 1). A summary of responses to Q1-4 is provided in Figure 2.

AUDIO FEEDBACK QUESTIONNAIRE: CHE-20004/6 Lab Diary Assessment

Please circle your choice of answer, use boxes for additional comments where appropriate. If you have any other comments, please use the back of the sheet.

1. Have you received audio feedback before (if answer is **YES**, please provide details)? Yes No
2. Did you listen to your audio feedback on the CHE-20004/6 Lab Diary assessment? Yes No
3. Did you listen to your audio feedback whilst looking at your lab diary? Yes No
4. Did you listen to your audio feedback more than once? If **YES**, why was this? Yes No
5. What did you like about this audio feedback?
6. What did you dislike about this audio feedback?
7. Please suggest how the audio feedback could have been improved:
8. Would you have preferred an alternative form of feedback on your CHE-20004/6 Lab Diary assessment? If so, what would you have preferred?

Written **Face-to-Face** **Peer (from classmates)** **Other (please specify below)**

9. For what types of assessment do you think this form of feedback would be most useful?

Poster **Lab Report** **Class Test** **Examination** **Other (please specify below)**

Figure 1: Questionnaire on audio feedback issued to 2nd year chemistry students

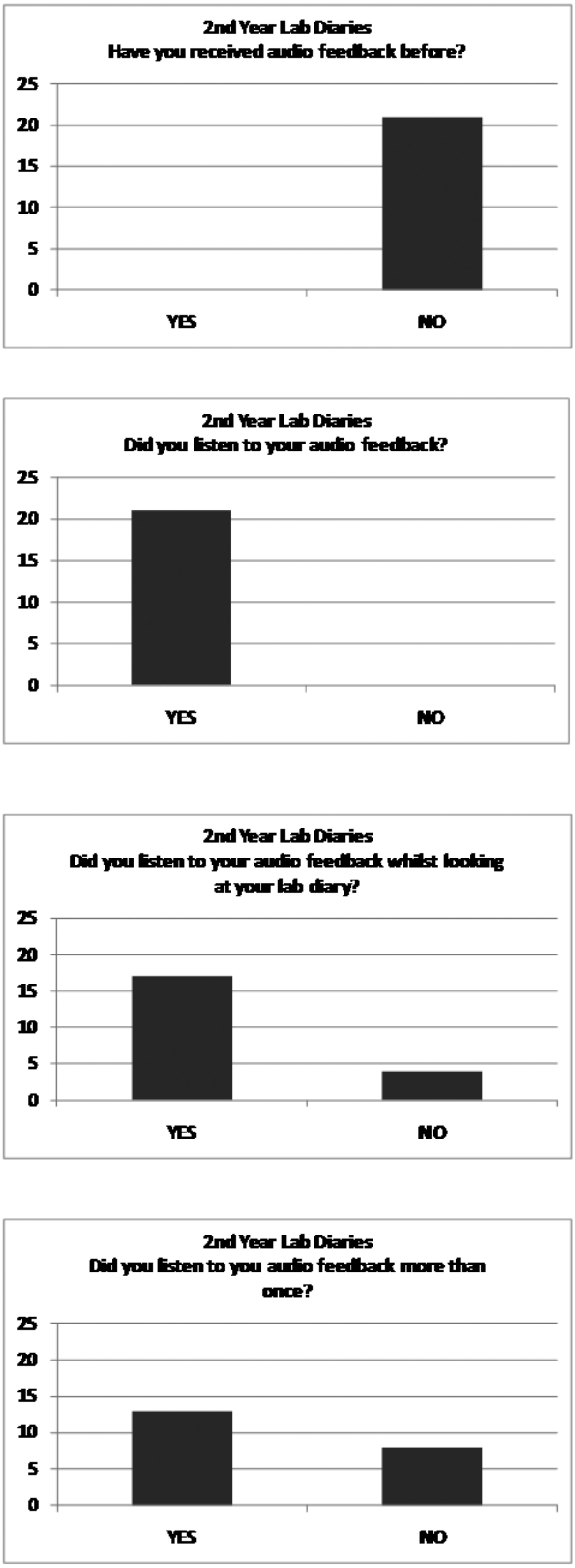


Figure 2: Summary of responses to Q1-4 (see Figure 1)

The novelty of audio feedback to students is clear as no students (in this survey and others) said they had previously received feedback in this way. In this particular group of students 100% of respondents said they had listened to their audio feedback with 81% listening to the feedback with their work in front of them and 62% indicating they had listened to the feedback more than once. Typical reasons given for listening to the feedback more than once (~2/3 of respondents cited a reason) are listed below:

> *1st time just looking out for score. 2nd time listening to the feedback.*
> *To fully look into areas of improvement needed.*
> *Once without lab diary, then again with.*
> *To go through the feedback again.*

Questions 5-7 invited open response comments with 100%, 48% and 19% of respondents answering Q5-7 respectively. For Q5 (*what did you like about this audio feedback?*), there was frequent reference to the level of detail in the audio feedback and some students contrasted this with written feedback. A selection of representative comments is listed below:

> *Very in-depth, more information given than written notes.*
> *It was more detailed than having notes in the lab book.*
> *Better than illegible handwriting.*
> *Specific to me, better feedback than a poorly thought out written assignment as with most other subjects. This combined with annotated feedback on lab report was excellent to really identify specific areas to improve.*
> *Worked very well if you had your lab book with you. More in-depth than written notes.*
> *It was less formal and stressful than a face-to-face interview. I also enjoyed the ability to pause (I could then take notes). I could also go back and listen again for reference in other lab books in other modules.*
> *Explained notes in book in more detail. Better than face-to-face because you can listen again.*
> *Was good going through the feedback while going through lab diary. Feedback more detailed.*

For Q6, (*what did you dislike about this audio feedback?*) although only a few students provided a written answer, the issues mentioned most frequently by this group of students were the lack of opportunity for contemporaneous dialogue and navigational issues (see below). Only one student said audio feedback was not as effective as written feedback.

> *Not as effective as written feedback.*
> *Having to replay it if you want to hear it again. Not able to ask questions.(4 students)*
> *No chance for questions or interaction – would prefer face -to-face with notes.*
> *Questions could not be asked at the time.*
> *I couldn't easily skip bits to hear the parts I wanted to hear again.*

Only a few students answered Q7 to suggest the inclusion of video or to conduct the feedback face-to-face (it was not stated that this should be captured in a recording, but this is the implication and is an idea that has been reported recently in the context of recorded personal feedback conversations in the laboratory[6]).

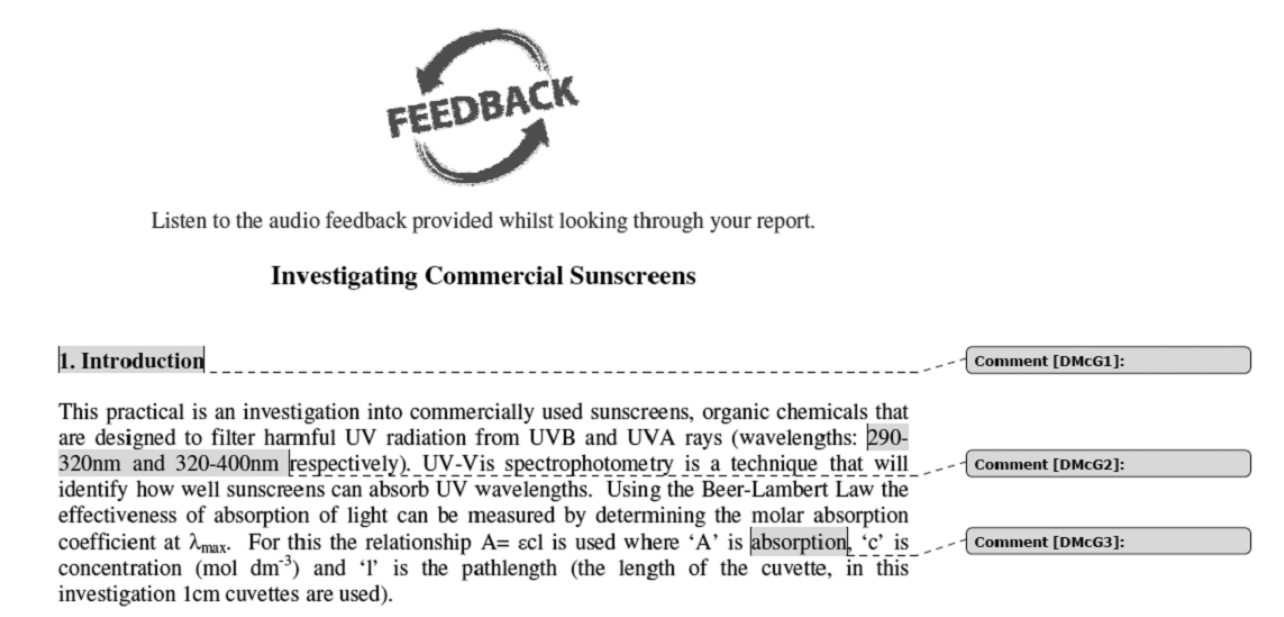
For Q8 (*would you have preferred an alternative form of feedback?*), 52% of respondents cited face-to-face feedback, but only 5% of students cited written feedback.

Similar themes arose with the feedback from 1st year students, although the enhanced comprehensibility of audio feedback was more clearly evident in these students' comments. This cohort of students was specifically asked to explain whether they preferred audio or written feedback. Issues of accessibility and navigation of the audio feedback problems (see below) were particularly prominent in these students' comments:

> *I liked the fact that it was very specific to my own work and the fact that I could listen to it whilst scanning through my lab book to see areas in which I could improve.*
> *Listening to the lecturer's voice, the improvements into my work along with the merits gets in more, than if it were written, and I also like to hear the different tones on the voice stressing improvements.*
> *It allowed me to clearly understand any mistakes I made, as opposed to written feedback, which can sometimes be confusing.*
> *I feel that more detail was given than would have been in written feedback.*
> *It gave me more information and everything is explained better and more than when it's written feedback.*
> *I personally prefer written feedback as I find it easier to refer back to; however with the assessment of a lab diary I feel that audio feedback is particularly suitable. The marker would otherwise have to either write all over the lab diary or virtually write an essay in order to deliver the kind of detail that was given.*
>
> *I preferred written feedback as I felt fully informed as to what I generally needed to improve on and what I did well in. With the audio feedback, I got easily bored and therefore didn't feel motivated to listen to it all, whereas for the written feedback I could easily scan through what was said and refer back to it whenever I needed to.*
> *It is not as easy to refer back to when completing future work for example; you would probably need to listen to the whole thing again to find a particular point.*
> *As it is audio, we always have to replay it to look over it and if we only need a specific part to look at then we will have to find the exact part from the audio.*
> *I prefer written feedback on my work as it is easy to look over it and it's easier to understand the mistakes if it is written on the same page. I don't mind audio feedback either, but the only disadvantage I found was if we need a specific part from the lab diary, we will have to find the exact part from the audio.*

Tutor Evaluation

From a practical point of view, the use of audio for feedback is ideally suited to the complexity and variety of work contained within a laboratory diary. It is comfortable to browse through a laboratory diary and to speak rather than write comments, with the only work your fingers are engaged in being the turning of pages and depressing the pause button on the digital voice recorder every so often. However, interruptions whilst recording audio feedback are more disruptive than for writing feedback, simply because you may lose your train of thought and you cannot 'see' what you have previously said so readily. The student feedback is highly positive and the increased detail in the feedback provided using audio rather than written feedback is borne out by the students' comments. The principal drawbacks cited by students appear to be related to ease of accessibility and navigation.


FEEDBACK

Listen to the audio feedback provided whilst looking through your report.

Investigating Commercial Sunscreens

1. Introduction

Comment [DMcG1]:

This practical is an investigation into commercially used sunscreens, organic chemicals that are designed to filter harmful UV radiation from UVB and UVA rays (wavelengths: 290-320nm and 320-400nm respectively). UV-Vis spectrophotometry is a technique that will identify how well sunscreens can absorb UV wavelengths. Using the Beer-Lambert Law the effectiveness of absorption of light can be measured by determining the molar absorption coefficient at λ_{max}. For this the relationship A= εcl is used where 'A' is absorption, 'c' is concentration (mol dm^{-3}) and 'l' is the pathlength (the length of the cuvette, in this investigation 1cm cuvettes are used).

Comment [DMcG2]:

Comment [DMcG3]:

Figure 3: Extract from an assessed laboratory report that accompanies audio feedback via an mp3 file

Audio Feedback on Laboratory Reports

Laboratory reports come in a variety of formats, but the reports for which audio feedback was provided in this work are formal structured word-processed (1000 words) reports, submitted and returned electronically via the VLE. Of course, there is no reason why feedback in audio format cannot be provided on hard-copy reports and assignments in a similar manner to that described for laboratory diaries above.

Practical Aspects

Audio feedback on laboratory reports was provided for two groups of students in 2010-11; 1st year chemistry (entire cohort of ~100 students, December 2010) and 2nd year chemistry (~50% of cohort (~30 students), March 2011, with the other ~50% of students receiving typed feedback from another tutor). In each case laboratory reports were word-processed (1000 words) and submitted online via the VLE. Marked laboratory reports with marks and embedded comment numbers (see Figure 3) and mp3 files were delivered to students individually within 2-3 weeks (2nd year) and 4 weeks (1st year). In recording the feedback, each audio file included the following introductory guidance comment to the student.

> *'This is the feedback on your lab report for CHE-XXXXX. I've placed comment numbers throughout your report and I will refer to these throughout this recording, so you will find it more useful if you listen to this feedback with your work in front of you'.*

The procedure adopted for assessing and providing feedback on laboratory reports was to read the report on-screen whilst simultaneously adding blank comments (occasionally words or short phrases were added as prompts for the audio feedback) using the comments facility within the review tab in MS Word. During this process marks were also assigned for the various aspects of the lab report against the assessment criteria (marks were provided in a table within the word document). This part of the process took typically 15 minutes. The audio feedback was then recorded using the comment numbers as navigational signposts for the students. The conclusion of the audio file included a short summing up and some specific advice on how the feedback could be used in future assignments (e.g. research project dissertations).

Student Feedback

Similar themes and issues encountered with audio feedback on laboratory diaries also arose with audio feedback on laboratory reports. Some representative feedback comments are provided below. The cohort of 1st year students was specifically asked to explain whether they preferred audio or written feedback, whilst 2nd year students were not specifically asked about audio feedback and their comments are unprompted within a module evaluation questionnaire (~30% of respondents highlighted audio feedback as an effective/ innovative aspect although only ~50% of the class had received audio feedback):

1st year students:

> *Before getting audio feedback I was certain that I wouldn't like it! However, for me, I find it more helpful listening to the comments rather than reading them. This is because the explanation of the feedback is clearer.*
> *The audio feedback is clear and easy to understand. Written feedback is occasionally difficult to read and understand, due to handwriting or the way the comments are written.*
> *It felt more personal and is more instantaneous because it doesn't have to be collected, it's accessible as soon as it's released and can be listened to anywhere.*
> *Written feedback allows me to jump to the exact point I am looking for rather than waiting for 'lecturer' to speak.*
> *Although audio feedback is useful, written feedback suits my learning style better and can be looked at in places when a computer is not available.*
> *I like both audio and written. Written is more permanent and you can pick it up and look at it any time and audio gives more detail so both cover everything.*

2nd year students

Audio feedback was very, very good!! Helped me to see exactly where I went wrong!

Particularly grateful for the audio feedback on the lab report. Very effective.

Audio feedback was very helpful.

Tutor Evaluation

In our experience opinion is divided amongst teachers in UKHE as to preferences for on-line versus hard-copy assessment of assignments. The provision of detailed handwritten or typed feedback on student assignments is undoubtedly time-consuming and the level of detail that can be provided is severely limited by the time required to write or type the feedback comments. With our experience in the provision of both audio and typed feedback, our findings suggest that the time taken to assess a word-processed laboratory report on-screen and provide feedback via audio is certainly not more than the equivalent process where feedback is provided via typed comments; indeed, if can be less by 10-20% although this is likely to be both tutor and assignment dependent. What is clear from the student

Student feedback on audio suggests it is richer, more detailed and more comprehensible in comparison with written feedback...

feedback is that the feedback provided to students via audio is richer and more detailed than is possible to provide via handwritten/typed feedback within the same timeframe. It is simply not practical to write what can be conveyed so concisely via the spoken word, where the desire to elaborate upon a particular point and/or to cite illustrative examples is not constrained to the same degree by time considerations. A disadvantage is its immediacy on returning to the feedback at a later date (as a student or tutor). Typed comments within a word document and their links to a particular section of the student's work are simultaneously and immediately visible, which is not the case for audio, and this has been cited by some students as a drawback of audio feedback.

Conclusions

The use of digital audio for feedback on assessments is straightforward to implement and provides a low cost alternative to written feedback on both hard-copy and electronic assignments. Student feedback on audio suggests it is richer, more detailed and more comprehensible in comparison with written feedback (handwritten/typed), although some students indicate they would still prefer to receive written feedback and highlight some drawbacks associated with accessibility and navigational issues with audio. We are now working to design curricula that will enable our students to develop the skills required to engage routinely with a variety of feedback in a systematic and meaningful way[9], forming part of the increased focus on development of graduate attributes/employability skills. As part of these developments we have started to accommodate, as far as practical and on a limited scale, students' feedback preferences and it will be interesting to see how prominently audio feedback features as and when it becomes more commonplace and whether audio-based feedback modes are demonstrably more effective than written feedback. It is clear that there is considerable scope to extend the use of emerging digital audio and audio-visual technologies to diverse areas of teaching and learning in UKHE.

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SEPnet Outreach: building and sustaining links between university physics departments

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A portfolio of activities has been developed that builds on the strengths of each department to deliver higher impact through collaborative development and delivery.

Abstract

The SEPnet Outreach work strand is a collaboration between university physics departments around the South East of England as a direct response to the national STEM agenda and the recruitment needs of the partner departments. A portfolio of activities has been developed that builds on the strengths of each department to deliver higher impact through collaborative development and delivery. In particular, the two year repeat contact 'SEPnet GCSE Programme' shows that a region-wide programme drawing inspiration not just from the physics departments but the school teachers they work with can be particularly effective. This paper looks at the successes of the activities so far, and takes a look ahead.

Introduction

In 2008 HEFCE awarded £12.5 million to a consortium of physics departments in the South East of England to support and sustain physics as a subject. Prompted by the closure of many physical sciences departments in 2006 the fledgling consortium tasked Nigel Brown and Associates to produce a review of the state of university physics in the South East[1]. This review highlighted various vulnerabilities, a message reinforced when the physics department at the University of Reading closed. As a response the group worked with HEFCE to gain financial support from the SIVS[2] (strategically important and vulnerable subjects) programme. This grant was awarded to the consortium to support physics on multiple levels increasing sustainability in the departments. By this time the consortium had settled to include six universities: the University of Kent; Royal Holloway, University of London; Queen Mary, University of London; University of Southampton; University of Surrey; and University of Sussex. The University of Portsmouth and Oxford University both held Associate partner positions due to their participation in the SEPnet-Astro research theme until mid 2010 when Portsmouth launched their new undergraduate physics degree and became a full partner. Oxford continues to have strong links not just to SEPnet-Astro but to the Outreach strand as well.

A significant factor highlighted by the Brown report, reflecting national STEM (science, technology, engineering and mathematics) policy thinking[3, 4, 5, 6, 7] at the time, was the shortage in applications to undergraduate physics degrees, and consequently a low undergraduate population. Recommendations included the formulation of a regional structure to support the existing outreach provision, and production of a knowledge base for the partners building on and complementing existing AimHigher frameworks and Institute of Physics (IOP) initiatives. The resulting SEPnet Outreach work strand forms a significant part of the SEPnet project. Each partner site has a designated delivery budget and Outreach officer for physics to enable regional delivery of outreach activities from the departments. To ensure that delivery is region-wide and to enable practice transfer between sites there is also a Director of Outreach for the consortium, facilitating strong links to the IOP, HE STEM programme and other STEM agenda initiatives.
This paper will provide an overview of the SEPnet Outreach strand, looking at the impact this has had on the departments and local schools to date, and the plans to sustain the activity beyond the end of the funding period.

SEPnet Outreach

Whilst acknowledging a need to drive up undergraduate numbers, the SEPnet Outreach strand was tasked to look beyond recruitment, using Outreach as a catch-all term for enhancement and enrichment activities, inspirational activities and wider public engagement. Time limited by the HEFCE grant which ends in 2013, the key audiences for interactions were identified as those at key stages four and five, studying for their GCSEs and A-levels. The perception was that any outreach activity carried out on a regional level would contribute towards the number of students interested in and qualified to take up a degree in physics, but would not be able to be tracked directly to recruitment numbers in the individual departments. It was however noted that anecdotally departments with active outreach programmes appear to recruit better than those that do not, and where the driver for such a programme (e.g. Outreach Officer) is removed a subsequent drop in undergraduate application can often be seen.

There were many logistical issues in getting SEPnet off the ground, including delays with recruitment of the central staff. Outreach was one area all partners could agree needed to be addressed quickly if it were to have a tangible effect, and so the flagship SEPnet GCSE Programme was used as a tool to bring the partners together. Other initiatives followed, and the GCSE Programme itself has been re-envisioned now that all the staff are in place, but in the beginning it served as a good testing ground for working together and forcing the departments to think beyond their own specialties and needs.

Collaboration

Imposing a network on the departments involved does not mean that they will find it easy to work together. Finance can be an effective lever in getting people to say they will engage, and even to take actions that look like they are doing so. The real collaboration can only start when the people on the ground, developing and delivering activities, are enabled to share practice and ideas and feel rewarded for doing so.

To this end a culture shift has been necessary in many of the partners. All of the departments in the network carried out outreach of some kind prior to SEPnet, such as lectures to schools or interest groups, hosting campus visits and student placements, or engaging with national schemes such as STEM ambassadors. So there was no doubt that the will to share knowledge of and passion for physics was there. What was missing in most cases was a rationale behind the interaction, other than thinking it might be a good idea.

The introduction of SEPnet Outreach provided a chance to pause and rethink what activities were on offer, and why. Regular meetings and discourse between staff both within their departments, and across the network has been invaluable in highlighting effective practice, and showing where efforts were being duplicated or even wasted.

Our structure includes:

- Regular officers group meetings for the dedicated SEPnet staff, often involving training
- Regional steering group meetings, for the Officers and other interested partners to guide the programmes
- Teacher Advisory group meetings, where teachers representing the range of schools we work with have a chance to tell us what they and their students need
- Use of the SEPnet governance to engage with Senior management in the partner universities

Getting this structure right has taken time, and it continues to evolve to meet the changing conditions in HE and schools. SEPnet is in a position now that includes a good mix of knowledgeable professionals to drive outreach activity in the departments, but that also has the buy-in of departmental staff and local schools. Activities that already existed have been guided to the best audiences, reinvigorated and renewed by idea sharing and in some cases have been stopped. New activities are designed to build on the strengths and research specialties of the individual departments, but also those of the network, and are always targeted for their audience. Undergraduate and post-graduate students are keen to engage. Increasing numbers are trained to help with delivery of activities, becoming strong communicators and great ambassadors for physics.

Underpinning all of this are the joint projects that are delivered regionally by all the departments, developed together, guided by audience need and providing high visibility through scale of delivery. The GCSE Programme provides a bank of activities for the partners that are curriculum relevant but draw out research highlights. Activities can be added or removed as necessary, but the underlying structure provides regular contact for schools, building up their relationship with the universities, and opening up other opportunities.

The GCSE Programme

- What is Physics? Taster session: a half-day on-campus activity that includes lectures and a carousel of large hands-on experiments, currently themed around Energy
- In-class activities: sessions designed to fit into a single lesson, covering curriculum topics. Includes Rollercoaster Physics, Radical Radioactivity, A walk through the EM Spectrum
- How to Ace your a-Levels: a full-day on-campus activity introducing core A-level physics topics and the maths that supports it all.

Importantly for SEPnet, this programme represents the results of ongoing teacher consultation. Previously there had been a lack of knowledge in the departments about changes to the curriculum and teaching in schools, and consequently a lot of guesswork being used, which has now been mitigated. Each in-class session can be delivered by the universities, but the teachers are encouraged to spend time with the equipment, and even to borrow it for their own classes. In this way we are providing a professional development opportunity without pressure, particularly useful for non-specialist teachers.

Results

Each department within the network has its own strengths and research specialties. Naturally these are represented in the portfolio of outreach activities on offer. The majority of the outreach work carried out by the departments before SEPnet was introduced fell into the ‘inspirational’ category, but now would qualify as enhancement and enrichment. The main collaborative projects have elements of both within them, and make best use of the dedicated Outreach staff in introducing schools education terms and processes to the departmental staff and students. All activities are developed in an environment of shared knowledge and resources, but some projects show this more than others. Particularly strong joint projects include LightTAG[8], an arts and science project for NEETS that resulted in a travelling exhibition currently touring the region, the SEPnet Physics Olympics, which will see groups of A-level students competing in physics challenges based on Olympic sports.

Response so far has been overwhelmingly positive. The GCSE Programme saw 55 schools attend the introduction sessions on campus in 2010, whilst over 300 schools engaged with the wider programmes. Workshop sessions are well received in school, and are being used outside of the project for training student outreach ambassadors and delivery as standalone activities. Teachers are using contact through promotion of this scheme to allow them to engage with the departments in different ways, often leading to lectures or open day visits, whilst at the same time the teacher advisory group is being used as a resource for the development of other outreach activities both regionally and locally.

Knowledge of schools and the issues in science teaching is seeping into departmental staff, and with it has come acknowledgment of the importance of having a dedicated member of outreach staff with professional skills.

It will take time to see the full impact of the programme on the school students and teachers, and may be impossible to link this activity causally to undergraduate recruitment, but the consequences can already be seen in the departments. A shift has occurred in the perception of the role of the outreach officer. Knowledge of schools and the issues in science teaching is seeping into departmental staff, and with it has come acknowledgment of the importance of having a dedicated member of outreach staff with professional skills. The departments have in the last month signed up to continue SEPnet Outreach indefinitely beyond the HEFCE funding period, acknowledging the value of the departmental and central staffing positions, and each contributing to the funds needed for these roles. The HEFCE funding has provided great start-up security, allowing the session materials to be developed and rolled out to all departments. With a bank of evaluated activities behind us, from here-on out the focus will be on sustaining delivery levels and working with as many young people and teachers as effectively as possible.

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The many positive impacts of participating in outreach activities on postgraduate students

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Postgraduate students are excellent role models for school students, where their passion and energy play a vital role in engaging younger students...

Abstract
Postgraduate students are excellent role models for school students, where their passion and energy play a vital role in engaging younger students and spreading enthusiasm and excitement about science. However, participating in outreach is not a one way activity for these postgraduate students. Through focus groups we show that the postgraduate students perceive that there are many benefits for themselves. These benefits are identified and discussed. This paper also contrasts the postgraduate with their undergraduate counterpart in terms of their contributions to engagement activities.

Introduction
Roberts and Wassersug[1] analysed data from an annual hands-on science summer school run for high school students between the years 1958 and 1972. Their data indicated that students who were interested in science and had an opportunity to participate in hands-on science research at school were significantly more likely to enter and maintain a career in science compared with students whose first experience did not occur until university. Their study provides quantitative support to the assertions that participating in hands-on science predisposes participants to having a positive attitude to science were made by Russell *et al.*[2] and Hanauer *et al.*[3] Gibson and Chase[4] showed that attitudes towards science were significantly improved when a hands-on (inquiry based) science program was employed in middle schools. Therefore, there is evidence that hands-on science interventions at school have a long-term impact on school students in terms of their attitude towards science, and there is higher chance that students will go on to science careers. Many studies describe a range of hands-on activities that are effective and their positive impact on students[5-12]. However, a key element of these successful activities is the provider; in these studies they feature either undergraduate students[13] or postgraduate students as a key component of the provision[5]. In both cases these students are excellent role models for school students; their enthusiasm, energy and the effect this has on enthusing and inspiring students is well documented. There are several schemes in place that facilitate undergraduate student participation in such activities for example, the Undergraduate Ambassador Scheme in the UK[14,15]. Undergraduate students can use timetabled free time during term-time where that exists, to devote to such schemes and these schemes have been shown to be effective. However, for postgraduate students to engage with these activities they need to take time out from their research and there may be a variety of barriers to this, e.g. resistance to being released by supervisors. In this paper we look at the positive impacts that postgraduate students have on engaging with school students and their teachers and the many benefits they themselves experience during such interactions.

Bristol ChemLabS Outreach has a wide portfolio of activities that engage with primary pupils, secondary students and members of the wider community. Activities include lectures, demonstrations, spectroscopy tours, schools conferences, competitions, domestic and international residential schools and laboratory based workshops. Annually 27,000 to 30,000 people are engaged in the outreach activities which require considerable postgraduate input. There are 260 PhD students in the School of Chemistry, and a large number of these volunteer for STEM Ambassador[15] and internal training to enable them to be involved in outreach activities.

Methodology
In addition to obtaining feedback from school students, teachers and event organisers, feedback from participating postgraduate students has been sought. On two separate occasions (2008 and 2010), all postgraduates involved in outreach were invited to lunch. On the walls of the lunch venue were put A0 sheets containing questions, marker pens

and post-it notes. The students were allowed to populate these areas with whatever feedback they wished to provide and to read previous input and comment upon that. Therefore, the informal input was both individual and collective. The responses of the first focus group were collected and categorized which led to several questions which were asked of the second focus group, as well as providing an opportunity for open feedback. Responses from both groups are reported here.

General observations comparing postgraduates with undergraduate ambassadors
Both undergraduate and postgraduate students have the advantage of youth over academic members of a university department, who are typically aged between 30 and 70 years old. School students generally find it easier to identify with people closer in age and outlook to themselves, so undergraduate and postgraduates can often be excellent role models for them

Several postgraduates have remarked that it is a challenge to explain what they are researching to a primary school student. However, they found training exercises extremely useful when discussing their research...

Postgraduate students are more likely to be available for whole day events rather than typical science and engineering undergraduates. At Bristol, undergraduates are not allowed to miss lectures, seminars, laboratory time or workshops to participate in outreach, many of which are whole day activities. Unlike most undergraduates, postgraduates have gained teaching experience through the delivery of seminars, workshops, tutoring to small groups and in demonstrating in the university teaching laboratories. Postgraduates do have a richer science background and a more rounded (and possibly higher) level of understanding of their subject. They have their PhD, research to talk about with school students and teachers whereas the undergraduates could be seen as still being in education as they are still being taught. Postgraduates have been through the whole university first degree process whereas undergraduates are still going through it and this added experience is useful when discussing University first degrees with school students. The postgraduates may have also experienced other universities and university types for example campus versus city-based, and many are from other countries. A more subjective observation is that postgraduates tend to be more self-reliant than undergraduates, a feature of the PhD program.

General comments on what University students get out of engaging in outreach?
Both postgraduate and undergraduate students have the opportunity to develop their communication skills[5] during outreach but the starting point is more likely to be advanced in the case of postgraduates as many already have teaching experience as part of their PhD. training. Communication skills, as part of a 'soft skills' set, are highly desired by prospective employers and further enhances the case for participation[16]. A specific element of communication skills that is particularly relevant to postgraduates is the ability to explain their research at a number of levels. Several postgraduates have remarked that it is a challenge to explain what they are researching to a primary school student. However, they found training exercises extremely useful when discussing their research with a wide variety of non-specialists and those with little science background. Indeed, one even had the chance to describe their research to a senior MP and was told that they had explained things most clearly!

Feedback from postgraduates and their discussion
What do you think the school students get from outreach activities?

Role modeling[9,10]
Several postgraduates commented on their use as role models: '*It's good that the students meet young people who do science so they don't just think that only old bearded men are scientists.*' Further it is still common to receive feedback on gender role models such as: '*Feedback from one primary school said the children were amazed to see "girl scientists"! I think this is* (outreach) *a very positive influence on young people* (in) *breaking down gender stereotypes from a young age*.'

Practical experiences that students cannot get at school[5,9,10]
Several commented on the practical activities undertaken during outreach. '*Students get the chance to carry out experiments they may not have been able to do at school and also the chance to work in state-of-the-art labs.' 'They* (the school students) *get exposed to aspects of science that aren't covered on the national curriculum. They see real scientists at work.'* '(They get) *the opportunity to do experiments using equipment that they probably don't have at school and spend time doing experiments which they might not have time to do at school.' 'For Primary school students they learn lots of science theory but don't normally get to put it into practice. The workshops give them the chance to do this.'*

Students' own personal development (skills)[5,10]
Through being involved in university-led chemistry outreach the postgraduates stated that school students gain greater confidence in their own abilities, improved their communication, team working, practical skills and learnt to deal with unusual situations. Several comments on the potential for students to consider their future careers, or at least see what a chemistry degree would be like, were made: '*Chance* (for school students) *to ask questions about what a degree in chemistry is like'.*

What is the difference in teachers' interactions with postgraduates compared with undergraduates?
It has been observed for more than a decade[9] that chemistry teachers enjoy conversing with postgraduates about their research. Indeed, postgraduates have been used to deliver Continuing Professional Development (CPD) to teachers especially in the areas of spectroscopy/spectrometry and electron microscopy. Teachers often value the chance to learn about the very latest research or developments in different fields. They often comment that they feel 'outside' the scientific community and, despite their intrinsic interest, have few opportunities or little time to update their science knowledge. Postgraduates also deliver short lectures to teachers when they are removed from their students during competitions. Topics have included extremophiles, the chemistry of chocolate and silicone polymers. This allows teachers to gain insight into current research. Teachers also question the postgraduates about their experiences of being a student at Bristol or further afield if they read their first degree elsewhere. Whilst undergraduate chemists can answer the last question on their experience of studying at Bristol they cannot be used to deliver all the other areas as they lack suitable experience or expertise.

What do postgraduates get from Outreach Activities?
The expected responses of '*Respite from research!*', *'It's great fun'* and '*Getting paid'* were recorded as well as a range of comments concerning science communication, development of skills and enhancement of confidence. The following are some representative responses: *'Practice at communicating science to different target audiences at different levels', 'An opportunity to learn how to share knowledge with people with a completely different level of knowledge of the subject.'* and, from a Chinese student *'A good chance to communicate with kids and practice speaking English.'*

Surprisingly comments such as '*The opportunity to watch some entertaining lectures*,' *'Know that you don't want to be a school teacher'* and '*Working with young children and sharing the enthusiasm I have for science*' were also recorded. The social aspects were also presented including: '*The chance to meet people in Bristol who are not students*.' and '*meeting other postgraduates*.' The latter is something that is often ignored, but for postgraduates to flourish, particularly those in small research groups, having a wider group of friends and colleagues is helpful. In terms of research, it has been observed that postgraduates studying seemingly disparate areas have found common ground that has aided both projects. For example, one postgraduate routinely used a particular analysis technique and in conversation with another postgraduate was able to share that technique and its benefits. The result was that the recipient then started using this analysis to great effect.

Justification as to personal involvement in outreach was given by one postgraduate: '*A friend of mine told me recently he can still remember the day his school had an outreach (or similar programme) visit. I like to think I made a difference and will be remembered by the children. He's now a chemist by the way!*'

What do you think schools get out of Outreach activities?
Comments were spread between those with experience of primary schools versus secondary schools.

Primary schools
Postgraduates felt that '*schools can provide a wider educational experience that doesn't have to stick to the national curriculum'*. Also A: **'***Help in the classroom, teaching support for a topic that they may not be their specialist subject'***,** *reach more kids with science***,** *make science more accessible and enjoyable and* (carry out more) *diverse activities'.*

Secondary Schools
Students that are '*hopefully more inspired and interested in chemistry'* who have had the *'opportunity to use more advanced kit (UV spectroscopy, infra-red etc) to back up what they're taught at A level, GCSE's, and see it happening, not just in a book!'*

Schools in General
Teachers get: *'expertise in an area of chemistry perhaps not known to them*', and '*get to see things maybe even they haven't heard of/seen such as ferrofluids. This can lead to new ideas in the classroom for practicals.*' Outreach is also seen as an opportunity to '*Give teachers a break' and to 'refresh their knowledge'.*

Commenting on the numerous photographs taken for websites and newsletters it was perceived that: '*Schools become more popular and parents are attracted to these schools'.*

What sort of additional activities do you think we could offer as Outreach?
A large number of responses were connected with providing careers advice to youngsters or involvement in some form of a student tutoring scheme. Some suggested expanding outreach to adults/ the general public and in promoting chemistry through competition '*In Ireland we have "Young Scientist of the Year" competition. Is there something like that here?'* Competitive activities such as the Royal Society of Chemistry's 'Top of the Bench' and Analytical Competition' were and are already being held. Additionally it was suggested that Bristol ChemLabS gave help with after-school science clubs. One student looked at this question in an entirely different way requesting that Bristol ChemLabS Outreach provided resources on '*How to get involved in jobs which would involve outreach/public engagement.*'

What are the less positive aspects of doing Outreach Activities?
The expected comments regarding commitments and attitudes of supervisors were present: '*I would love to get involved more but can't afford the time*', **'***I think outreach activities are rewarding for both Postgrads and pupils but they are not necessarily supported by all academic supervisors'* and *'Some supervisors do not recognize the value of outreach activities*'. Proposals to reduce the time-commitment and avoid supervisor conflict included having some outreach at weekends. It may well be the case that with Impact Factors associated with research grants becoming ever more important, supervisors may be less reluctant to allow their students to engage in science communication [17,18].

Other negatives commented on were *'early starting hours'* when schools need an 8:45 am start and are 2 hours drive away, when students '*misbehave or don't listen'* and *'sore throats!'*

Other Comments Made

The progression and recognition of science communicators/ outreach workers was brought up on more than one occasion: '*Perhaps there should be a structure award for participants in Outreach – bronze, silver gold etc. Currently outreach isn't part of our assessment, although it takes up research time and is not necessarily valued by supervisors. An award would indicate valuable skills*.'

One postgraduate also made a request for '*small amounts of cash for development/ implementation of novel projects.*'

Concern was expressed that only the most able school students are given the opportunity to engage in outreach: one postgraduate commented '*I would discourage just taking the 'best' students academically for special treatment from Outreach. Often the 'best' academic students are the best crammers and not the best scientists. The mid-range students can do science too!*' Much of Bristol ChemLabS outreach is decided by the teachers who organise the visits. For those visiting the School of Chemistry for laboratory work, the only request made by Bristol ChemLabS is that the students should be bright enough to successfully go on to the next stage of chemistry. Other postgraduate comments considered *'that it is important for pupils from less privileged schools to be exposed to the university experience and encouraged to apply to scientific subjects in particular'.* Here too, Bristol ChemLabS Outreach engages with the full spectrum of schools and their students.

The enjoyment for all involved was also commented upon: *'It's fun for the kids and for the postgraduates (if sometimes quite hard work) and often fun for the teachers.'*

What additional training could we offer to Postgraduates?

The few comments here were in terms of behavior management: '*Crowd control'* and amusingly '*How to control yourself when the children don't pay attention*.' Requests for training for practical activities have already been addressed. New postgraduate outreach workers who wish it are given a workshop on the primary experiments used. Those new to the main teaching laboratory experiments are brought in as super-numery demonstrators so they can get on-the-job training before they are tasked with full demonstrator duties.

Summary and Conclusions

In general, postgraduate students offer a superior mix of skills compared with undergraduates, from a range of observations made during the Bristol ChemLabS Outreach program. Practical considerations, such as their availability for whole day events, their experience in teaching, their more complete knowledge of the subject as a whole and their specific knowledge about their research, give them a distinct advantage over undergraduates. In particular, the interaction between postgraduates and teachers is much stronger than with their undergraduate counterparts, where considerable updating for teachers in the research field of the postgraduate is a common feature.

In terms of the benefits to postgraduates there are many beyond the usually reported communication skills, career benefits and confidence building[5]. Many report direct or indirect benefits to their research (e.g. having to really understand a topic that has helped their research or interactions with people outside their normal research arena including more postgraduates). Others value the opportunity to break out from research groups to make new friends, something that cannot be valued highly enough when postgraduates need support during their PhD.

A common benefit noted by postgraduates is simply providing a different activity to their PhD. All postgraduates need to be re-energised and refreshed from time-to-time and engaging with school students, their teachers and the general public gives this cohort a much needed buzz about themselves and science.

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All postgraduates need to be re-energised and refreshed from time-to-time and engaging with school students, their teachers and the general public gives this cohort a much needed buzz about themselves and science.

Screencasting as a means of providing timely, general feedback on assessment

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Abstract

Feedback has been highlighted as a key area for improvement in teaching in higher education following recent National Student Survey results. While feedback may be provided in a variety of forms, both general and specific to individual students, there is often a need to provide general feedback to a whole class without consuming valuable and limited contact time.

Screencasting involves recording a short video clip of a computer screen with narration. It can be used to demonstrate various computer programmes, how to perform data analysis and to provide feedback on assessment, both individually and to the class as a whole. Camtasia or other screencast facilities were used to produce short videos of solutions to problem based assessments, incorporating general feedback and addressing misconceptions that had arisen. The resulting video files can be made available through virtual learning environments or on external websites giving the students round the clock access to a 'mini lecture' enabling them to use the feedback at a time and place of their choosing. We have experimented with screencast feedback in a number of chemistry modules, focussing on feedback for in-class tests and problem-solving activities.

In this communication we will look at screencasting as a means of providing efficient and effective whole class feedback, highlighting the strengths and challenges of this technology. We will discuss the experiences of both students who receive screencast feedback and tutors who provide it, and finish with our suggestions for best practice in the area.

While feedback may be provided in a variety of forms, both general and specific to individual students, there is often a need to provide general feedback to a whole class without consuming valuable and limited contact time.

Introduction

Feedback on assessed work may be defined as information provided by a teacher regarding aspects of performance or understanding and should show students how to bridge the gap between their level of performance or understanding and the level required to meet the intended learning outcomes (adapted from Hattie[1] and Sadler[2] contained within reference 1). Effective feedback from a student perspective must be timely and in a format that students can use in revision or in future assignments. Recent National Student Survey results have indicated that students are less satisfied with the speed of marking and feedback (Question 7: Feedback on my work has been prompt) and the ability of feedback to aid understanding (Question 9: Feedback on my work has helped me clarify things I did not understand)[3] . For staff, providing detailed feedback is often a trade-off between speed of marking, and level of detail required. It is also a source of some frustration when students continue to make the same errors despite apparently receiving detailed feedback on previous, related assignments.

Encouraging students to reflect upon feedback has been identified as the third step in assessment and feedback by Sergeant[4]. The first step, assessing the performance, can largely be separated from the second step, providing feedback. This may be useful for students who are unwilling to confront their grade, allowing them to engage in reflective use of feedback. By providing feedback on in-class assessment in the form of model answers with general comments, students may be more likely to incorporate that feedback in their revision process and therefore benefit more from it. Such feedback is also detached from assessment of performance, focussing on the level of understanding required more generally.

Chemistry and Medicinal Chemistry at Keele University has recently seen significant growth in undergraduate student numbers with first year class sizes increasing from 60 in 2008/09 to 100 in 2010/11. The challenges of providing detailed feedback promptly to students has increased proportionately with increasing student numbers, however a number of areas in which the feedback process can streamlined somewhat have been identified. These problems are similar to those faced by teachers with little scheduled contact time and when online instruction is indicated. Providing individual feedback on work is a time-consuming and often repetitive process, but a very necessary process. Providing whole class feedback is an opportunity to address problems more generally, particularly those that some students have not yet made. Feedback can be prepared and released very rapidly after an assessment, even before grades are returned to the students.

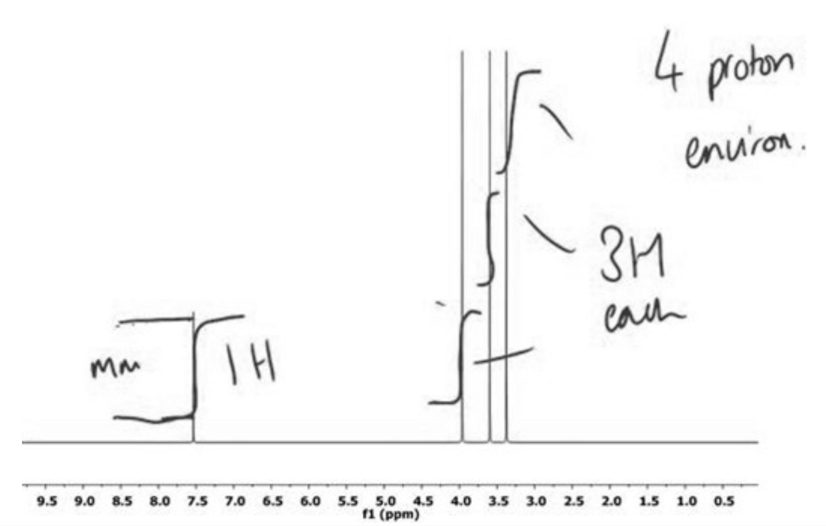

Figure 1: Example of a slide produced during a screencast, annotated with the tablet PC

For many assignments such as class tests, model answers are often requested by students in addition to a grade and some individual feedback on the script. There are several advantages to providing these:

- Many of our students learn by doing and having a full set of answers to assess their attempts against is beneficial. Students have stated that they revisit and practice class test and problems class questions when revising for end of module exams.
- Students who have not engaged fully with the material at the time of the class tests may not know sufficient to make certain mistakes. For example, a student who has barely attempted to answer a question is unlikely to have made a large number of mistakes, and therefore will not benefit from feedback written on the script unless it provides the full, worked answer. Providing individual feedback on work submitted does not anticipate potential growth in their understanding that comes with revision and practice, and is therefore of limited longer term value.

We have provided typed or handwritten model answers for most class test questions in the past and this has been viewed as useful and adequate by our students. These model answers have often included more general key points of feedback such as 'remember to show all working' or 'UNITS!' An alternative approach is to use some teaching sessions to review assignments and to go through answers with the whole class, allowing greater interactivity. This is not always possible within the constraints of timetables, and may be off-putting for students who have performed well, leading to a lack of engagement.

Screencasting, also known as vodcasting, offers a means of providing mini-lectures working through answers to assessments that students can view at a time and place of their choosing, rather than being forced to listen in a timetabled class. Screencasts are a useful form of e-teaching, and have been successfully used in distance or online learning modules across many subjects. Crucially, screencasts of model answers and problem solving allow teachers to reveal their problem solving strategy, something not easily conveyed with written answers[5]. This whole class approach to feedback differs from the use of screencasts to provide individualised commentary on students work, also discussed in this edition of New Directions.

Technology Requirements

We use a Toshiba tablet PC running Windows 7 and Camtasia Studio 7[6]. Care must be taken when selecting a tablet PC to avoid modern touch screen portable tablets that do not have the processing power necessary to run presentation and screen capture software. Many modern tablets do not come with stylus pens suitable for written annotations, being largely designed for touch screen operation. Screencasts may be recorded using free websites such as ScreenR[7] or Jing[8] but are limited in length and editing facilities. The resulting screencasts are made available on websites. Audio must be recorded directly onto the computer when using these sites and a headset microphone may be useful to improve audio quality.

For screencasts recorded with Camtasia, a digital voice recorder was used in place of the internal microphone to record high quality audio which was then edited into the screencast. The screencasts were edited before production of the video to remove any awkward pauses or stumbles. This enabled the screencasts to be recorded in one attempt. Custom production settings were used within Camatasia Studio 7 to enable a table of contents to be produced in the finished video. This allows students to navigate to a specific part of the screencast, for example a specific PowerPoint slide title, enabling them to revisit content easily. Screencasts were approximately 5 minutes in length (the maximum length for online production) and took around 20 minutes to prepare, record and edit each after the initial learning curve (Fig. 1).

Examples of Use and Evaluation

First Year Chemistry

Screencasts were used to provide model answers to a number of class tests in the 2010/11 academic year including those involving spectroscopic data interpretation and main group inorganic chemistry. For first year Chemistry, screencast model answers and feedback were provided in addition to marked class test scripts, but the level of feedback offered on the marked scripts was reduced to only the key points and uncommon errors, and students were directed to consult the screencast model answer feedback.

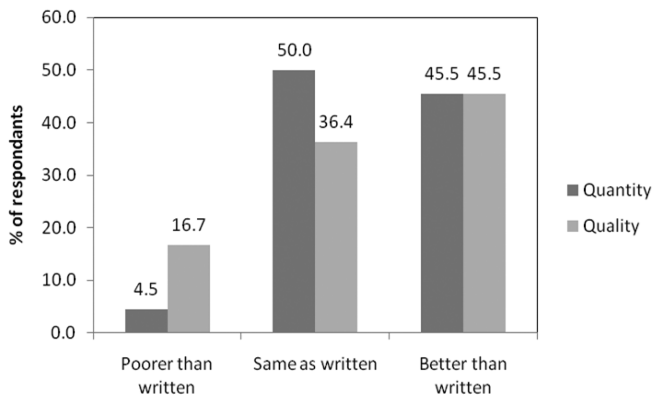

Figure 2: Question: think about screencasts as a way of providing feedback and model answers for class tests in first year modules. How does screencast feedback compare to written in terms of quality and quantity of feedback? Graph gives values as % of responses, 66 responses received from class of 90 students

To prepare the screencast feedback, PowerPoint slides were created with one question per slide with sufficient room for writing the answers, and a script was prepared by writing out the answers in full on a printout of each slide. An individual screencast was produced for each question to allow students to find the part they required more rapidly, and to reduce the demands on the working memory of the students[9]. Student feedback indicates that this should have been further broken down, perhaps into subsections of questions.

First year chemistry students were asked to evaluate the quantity and quality of whole class screencast feedback as compared to written feedback in a questionnaire about teaching methods conducted in March 2011.

The majority of first year students felt the screencast was equal to, or better than, written feedback in quality and quantity (Fig 2). Many students indicated that they would prefer written feedback as they could identify the specific area of interest more rapidly. Searching through a screencast for a particular section was identified as particularly frustrating; even from students who felt that screencasts on the whole were better than written feedback. While a table of contents, or recording short screencasts for each question can partly work around this concern, a copy of the annotated slides produced during recording can be provided. A text based version can be provided for students with specific needs if required.

> "*I found the video feedback to be very helpful. It allowed me to look at my answers in the comfort of my own home, without using up valuable problem class / lecture time. [The] commentary highlighted some points that would not have been easily conveyed in writing alone .*" – First Year Student
> *While the screencasts are better than written, they are also longer and therefore it takes more time to review a single question. Separate screencasts for each question could make it easier to sort through."* – First Year Student

Third Year Chemistry
A recent development in assessment in 3rd year chemistry at Keele is the setting of test questions based on research papers, requiring students to locate, extract and analyse/ interpret complex data and information. The examples for which screencast feedback was provided were based on advanced kinetics, activation parameters and inorganic/ organic reaction mechanisms. Although test questions are seen in advance, students did not know which would be selected for the summative test. Copies of the research articles were provided to the students during the test. This type of assessment was ideally suited to screencast feedback because it enabled the problem-solving process and thought processes of the tutor to be communicated in a manner that would be very difficult with static written feedback. The sequential introduction of material with forward and back referencing and supported by audio to emphasise key points and common errors adds additional dimensions to the feedback. The screencast feedback for these test questions was recorded, edited and produced using Camtasia on a standard laptop with in-built microphone, as an alternative to the tablet PC. PowerPoint slides were prepared in advance using animation to make parts of the answers appear as required. The class viewed this very positively resulting in a number (in 11 out of 25 questionnaires) of unprompted comments on the screencasts in end of module evaluations.

> *"This is a great tool to use when going back over questions, if I was just provided with the equations without the audio I wouldn't understand your thinking and also some of the basic maths (I don't think I could apply what I would see to another example)."* –Third Year Student

Tutor Experiences
Production of screencast feedback was more time consuming than simply providing written or typed model answers to the class, but student responses indicates that this is time well spent. Incorporating generic comments into the screencast such as indicating the most common errors and how to avoid them was extremely useful, giving a level of detail in the feedback that could not be achieved on individual scripts.

Summary and Suggestions for Best Practice
Our experiences of providing screencast feedback on problem solving questions to whole classes have been largely successful, and well received by the students. While there is an initial learning curve with this technology, the process can be extremely efficient. We have some suggestions based on our experience that may help anyone considering this method of feedback.

- Consider the length of each screencast carefully and break larger questions into sections.
- Stay focussed on the topic of the screencast and avoid incorporating additional examples or too many alternative explanations.
- Organise material logically to minimise demands on working memory.
- Write a script or plan for each screencast and follow it.
- Ensure that students have suitable access to computer facilities with sound and sufficient IT skills to access the screencasts.

- Ensure your audio is of sufficient quality – inbuilt microphones may lead to quiet recordings.
- Turn off email or other programmes – pop up notifications will be recorded on screencasts!

Acknowledgements
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On the impact of the Bristol ChemLabS' outreach programme on admissions to the School of Chemistry

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Abstract

Analysis of the average number of applicants received from schools that engaged in the Bristol ChemLabS Outreach program prior to a student's application with those that did not engage, shows a significant increase in applicants from engaged schools. The significance is weaker when just Post 16 students are considered but this is almost certainly due to a smaller sample size. When this analysis was inspected in terms of the distance of the school from the University of Bristol, there was an increase in the number of applicants from engaged schools irrespective of distance. However, a statistically significant increase was observed for schools within 50 miles of the University from an analysis of just Post 16 students. Students who applied to the department from an engaged school were more likely to accept an offer and also to make the department their firm acceptance. A slightly higher number of applications that were rejected came from engaged schools too. There are two possible reasons; first, the engagement may have encouraged more students who did not have the required entry qualifications. Second, during the period of analysis, the overall entry grades went up by one grade each year. Such a dramatic rise was probably the reason for the slightly elevated numbers.

Introduction

The numbers of applicants and acceptances from universities have been increasing overall in recent years[1]. However, there has been concern for some time about the decline in interest from young people in studying science and in pursuing scientific careers[2]. Interest in science outreach related activities has risen based on this, where the engagement activities often are concerned with encouraging interest in science and scientific careers[3-7].

...there has been concern for some time about the decline in interest from young people in studying science and in pursuing scientific careers

Following on from the original goals of the outreach program started in 2000, the Bristol ChemLabS Outreach activities[8-15] have the objective of promoting Chemistry on a national and even an international basis, without any emphasis on recruitment to the School of Chemistry at Bristol. In this way, activities are free from advertising and staff are under no pressure to compare recruitment statistics with outreach activity. This has been a very helpful approach and has allowed the Outreach team to take a long-term view in terms of their planning. However, after five years of the Bristol ChemLabS Outreach program it is interesting and appropriate to look back and compare these activities with data on applications and admissions to the School of Chemistry. Has the Outreach program had any impact on recruitment? This study compares applications from schools that have and have not engaged with Bristol ChemLabS in the years prior to the application being made and look at trends.

Research Questions

- What are the effects, if any, of a school's engagement with the Bristol ChemLabS' outreach program on the number of students applying to study chemistry at the University of Bristol?
- What are the differences, if any, between applicants to the School of Chemistry if the applicant's school had or had not taken part in Bristol ChemLabS outreach activities?

Methods

Sample

Application data to the School of Chemistry were obtained for the years between 2005 and 2008. This included applications for all chemistry undergraduate courses supplied by the department, for both immediate and deferred starts. Data were supplied in an anonymous format but appropriate for this research.

The following variables were available in these data:

- Year of Admission cycle
- Entry year applied for
- Course applied for at University of Bristol
- Decision/response at University of Bristol
- Gender
- Local Education Authority
- School
- Institution the applicant attended

These data were merged with information on which schools had engaged in the Bristol ChemLabS Outreach program and a variable was created to indicate this.

The definition of an engaged school included any secondary school that had engaged with Bristol ChemLabS outreach in the years prior to the students' application to the University of Bristol. This grouping takes into account students that may have been affected indirectly through their schools' interaction with Bristol ChemLabS, such as through recommendations by teachers or fellow students.

Data Analysis
The Statistical Package for the Social Sciences (SPSS) was used to run statistical analysis tests with data. Chi-square tests of independence were used to explore the relationship between engaged and non engaged applicants, and a number of variables. *Post-hoc* tests were used to further understand results of chi-square tests of independence, when more clarification was necessary. Independent samples t-tests were used to compare groups (engaged and non-engaged schools) in terms of the average numbers of students applying to the School of Chemistry.

Table 1: Average number of applicants per school to the School of Chemistry from 2006 to 2008

2006 – 2008	All Applicants	Engaged School	Non Engaged School
All students	2.54	3.10	2.51
A level students	2.54	3.30	2.52

Results & Analysis

1. Applications analysis
Table 1 shows that engaged schools showed a noticeably higher average number of applicants than schools that had not engaged with Bristol ChemLabS prior to the applications being made, both the Post 16 and complete cohort. An independent samples t-test was used to compare the average number of all applicants for both engaged and non engaged schools over the three years of applications from 2006 to 2008. For the entirety of these three years, engaged schools were found to have significantly higher average numbers of applicants than non-engaged schools (t (1370) = -1.981, p = .048 (two tailed)). For Post 16 students the t-test was bordering on significant (t =-1.923, p = .055 (two tailed)). Since the results are very similar to those obtained for the overall engaged group, reduced sample size could be a factor here.

2. Applications from Students Attending Schools in Surrounding Areas Engaging with Bristol ChemLabS
When considering the cohort as a whole engaged schools show slightly higher average numbers of applicants than non-engaged schools. However, the differences were not statistically significant for any of the areas when independent sample t-tests were used to compare the average number of applicants for both engaged and non engaged schools in each area. In a similar way, just the Post 16 cohort showed that in almost all locations, engaged schools show slightly higher average numbers of applicants than non-engaged schools. Independent samples t-tests were used to establish whether the difference in average number of applicants from engaged and non-engaged schools were significant. Table 2 shows the p-values that indicate that there are a significantly higher number of applicants per school for engaged schools within 50 miles of the University of Bristol, compared with schools in the same area that had not been engaged.

Table 2: Average number of applicants per school to the School of Chemistry based on school location during 2006 to 2008
** indicates difference is significant at the 95% confidence level or above*

Distance from University of Bristol	All Applicants	Engaged	Non-engaged	Sig. (2-tailed)
50 Miles				
Post 16	2.60	3.77	2.41	.017*
All	2.60	3.00	2.43	
Within 100 miles				
Post 16	2.82	3.30	2.77	.29
All	2.82	3.21	2.74	
Between 50 and 100 miles				
Post 16	3.01	2.36	3.05	.46
All	3.01	3.62	2.95	
Over 100 miles				
Post 16	2.45	3.27	2.44	.29
All	2.45	2.85	2.44	

3. Gender of Applicants and School Engagement
Schools engaging with Bristol ChemLabS had a slightly larger proportion of males applying to study chemistry at the University of Bristol than schools that had not engaged. The Chi-square test for independence indicated no significant association between school engagement and gender for the whole cohort, $\chi 2$ (1, n = 3585) = 2.9, p = .09 or from the group of just A level students, $\chi 2$ (1, n = 3585) = 3.8, p = .06.

4. Decision on Students' Applications
Analysis of applications showed that students from engaged schools were more likely to accept the offer made to them and indeed were more likely to make the department their firm acceptance. A downside was that engagement encouraged more students from those schools to apply who did not have the required entry qualifications, leading to a slightly higher number of rejections. During this time, the School of Chemistry raised their entry requirement by at least one Post 16 grade each year. This rapidly increasing entry requirement could also be responsible for the increase in rejections.

5. Applicants' School Type and School Engagement
There are no significant differences between the proportion of applicants from state and independent schools between applicants from engaged and non-engaged schools. Inspection of the proportions of applicants from each type of school by year indicates some variation over the three years for the proportions of applicants from engaged schools from either type of school, but these differences are not significant, and could be due to the smaller base sizes caused by the fact that applicants from Further Education (FE) colleges could not be included in the comparison.

Analysis of applications showed that students from engaged schools were more likely to accept the offer made to them and indeed were more likely to make the department their firm acceptance

Discussion

Applicants from Engaged and Non-Engaged Schools
Results indicate that there is a significant association between engaging with a school and the number of applications received. There are obvious potential reasons for the difference observed in average numbers of applicants such as that students experiencing the university may have liked particular aspects of it (such as the facilities they saw or the students they met) which may have impacted on their decision to apply. It may have been the only non open day contact they have had with University staff and students.

Another consideration is that schools engaging with Bristol ChemLabS (in fact, all schools that sign up to receive the CHeMneT newsletter) tend to be better performing than average, with more students than average taking triple science and Post 16 chemistry. This may mean that they have more students applying for university generally, and more students applying for chemistry or chemistry related subjects. This wouldn't necessarily explain an increase in applications to Bristol specifically, but could be a potential avenue for future research to see if engaged schools do have more students applying for chemistry at university, and whether or not those students show a bias towards applying to Bristol.

Table 3: Proportion of applications to study chemistry at the University of Bristol who are males and females from 2006 to 2008

		All Applicants	Engaged	Non-Engaged
Male	**All**	62%	67%	61%
	Post 16		68%	61%
Female	**All**	38%	33%	39%
	Post 16		32%	39%

Applications from Students Attending Schools in Surrounding Areas Engaging with Bristol ChemLabS
A comparison of the average number of applicants per school to the School of Chemistry at the University of Bristol was made, isolating schools within 50 miles of the university, schools within 100 miles of the university, schools within 50 to 100 miles of the university and schools over 100 miles away. In a comparison of all engaged and non-engaged schools, the findings demonstrated that in all areas, the average number of students applying to the School of Chemistry was higher in engaged schools than non-engaged schools. However, independent samples t-tests demonstrated that this difference was not significant in any area, near or far from the university. Comparing only those schools with engaged Post 16 students and those not engaging Post 16 students, the findings showed that in most areas, the average number of students applying to the School of Chemistry was higher in engaged schools than non-engaged schools. Results from independent samples t-tests indicated that this difference was significant for students from schools within 50 miles of the university. This suggests that students that potentially may not have applied to the University of Bristol from this area (perhaps because it was too close to home) did so after experiencing the university for themselves. Across the whole university the number of students applying from the southwest of England region is only 8-9%. The significant association between application and engagement with local schools is particularly encouraging. However, there was a change in the trend for schools between 50 and 100 miles from the university. Although not significant, schools from this area that had not engaged with Bristol ChemLabS had a higher average number of students applying to the University of Bristol than those schools that had engaged. The sample size for this particular analysis was very small, and given this trend does not occur when all engaged schools are used in the comparison, it could be that the small sample size had an impact on this result.

Gender of Applicants and School Engagement

In all applicants to the School of Chemistry, each year around two thirds of applicants are male, and one third female. In a recent report from UCAS, the UK university admissions service[1] analysis of university applications from 2002 to 2007 showed nationally around 60% of applications to study chemistry were from males. Comparison of applicants from engaged and non-engaged schools showed little difference in the proportion of males to females, both for all engaged schools and just those with engaged Post 16 students. Since only a few of the activities offered by Bristol ChemLabS are specifically to encourage female students' interest in chemistry (and these are at Key Stages 2-4), it is perhaps unsurprising that there is no change in this. The positive interpretation of this finding is that the activities of Bristol ChemLabS may be appealing to both males and females in equal measures, since the ratios of gender were not significantly different.

Decision on Students' Applications

Although there was no significant result in the *post-hoc* test for the numbers of engaged and non-engaged applicants declining a place at the School of Chemistry, inspection of the original results suggest that applicants from engaged schools are less likely to decline a place if they are offered one. The standardised residual for this group, (students from engaged schools that declined a place) although not statistically significant, shows there were less than expected numbers of applicants in this group. This may have been the case because many of these students may have had direct experience of the University of Bristol and the School of Chemistry, and so would be more likely to apply for a place only if they were reasonably sure they would want to attend the university. A similar pattern of results was observed in the comparison of schools with engaged Post 16 students and schools without, although this was not significant in statistical tests. Again, this may be due to the reduced sample size for this particular group.

> From 2006 to 2008, schools that had engaged with Bristol ChemLabS... had a significantly higher average number of applicants than schools that had not engaged

Applicants' School Type and School Engagement

There was no significant difference between applicants from engaged and non engaged schools in the proportion of applicants coming from state and independent schools, in both a comparison involving all engaged schools and that involving only schools with engaged Post 16 students. It has been established that Bristol ChemLabS has been engaging with a similar proportion of state and independent schools to that in the whole of the UK. The positive interpretation of this finding is that the activities that Bristol ChemLabS provide do not seem to appeal to students from one type of school more than another. It is important to bear in mind that this comparison did not take into account those students that had gone on to an FE institution to undertake their Post 16 studies, as it was not possible to tell what type of school they originally attended from the data available.

Summary

From 2006 to 2008, schools that had engaged with Bristol ChemLabS (with any age group) had a significantly higher average number of applicants than schools that had not engaged. Although this was only a small difference, it is an encouraging finding that suggests engaging in chemistry-related activities like those offered by Bristol ChemLabS may have an effect on students' further study decisions.

Further Research

If further research were to be undertaken, it would be useful to increase the sample size of applicants, in order to obtain more reliable results, and give a better chance of being able to obtain a significant result if there are real differences between applicants from engaged and non-engaged schools. Further research would also be interesting into the places that students from schools engaging with Bristol ChemLabS go. Although this research showed a slight increase in applicants to the School of Chemistry at the University of Bristol, it would be interesting to research whether engaged schools have an overall increase in students applying for chemistry related degrees at any university. It would be useful to gain information from both engaged and non-engaged schools on where and what university courses (including non-chemistry courses at Bristol) their students apply for, to establish if there is any overall difference.

Acknowledgments

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Combining screencasting and a tablet PC to deliver personalised student feedback

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Abstract
In many large research intensive universities in the UK the ability to provide a personalised university learning experience for their students is providing a serious challenge. Based on the National Student Survey (NSS) data, the absence of focused personalised feedback is often a concern of students. Here we describe how we use the combination of modern technologies encompassing a Tablet PC and screencasting to provide a personalised feedback to our students on submitted coursework and tutorial example classes. The fundamentals and practicalities of this approach, in particular with regard to the physical sciences, are described and data from student attitudinal and informational surveys are presented.

Introduction
Effective feedback is an essential part of the learning process allowing students to assess their comprehension and grasp of a particular topic and providing expert constructive advice on how to improve their performance[1]. To be effective, feedback needs to satisfy the following four criteria: it should be (a) timely, (b) meaningful, (c) constructive and (d) personal. The effectiveness of feedback in UK higher education has been questioned in recent years due to the low scores achieved by questions relating to feedback in the National Student Survey (NSS). Of the twenty one questions raised in the main questionnaire, feedback-related questions regularly achieve the lowest score. It is of interest to point out what specific questions concerning feedback are asked. Questions 7,8 and 9 relate to feedback and are given below:

7. Feedback on *my* work has been prompt.
8. *I* have received detailed comments on *my* work.
9. Feedback on *my* work has helped *me* clarify things *I* did not understand.

Effective feedback is an essential part of the learning process allowing students to assess their comprehension and grasp of a particular topic and providing expert constructive advice on how to improve their performance.

These questions in essence query directly three of the criteria for effective feedback described above. Question 7 addresses timeliness. Question 8 addresses the meaningfulness of the feedback given and question 9 addresses the constructive nature of the feedback. The other criterion, personal, is implicit in each question with the use of "I", "me" and " my" throughout.

Universities throughout the UK have been actively engaged in finding out student attitudes to feedback and trying to find ways to improve and adapt feedback to these student needs. An informative UK-wide survey of student attitudes to feedback is given by the Higher Education Academy at: <www.heacademy.ac.uk/resources/ audioandvideo/assessment>. From such surveys and the author's own discussions with students at the University of Manchester a significant student-perceived failure of feedback at university is the lack of the "personal touch" where the student needs their own particular problem to be addressed rather than general ones. In school students are used to a more personal relationship with their teacher and feel their personal development is being monitored. For a variety of reasons such one to one student-tutor teaching is no longer feasible in UK higher education. To address such problems others have looked at the feasibility of using technological advances in communication to facilitate more effective feedback. Of direct relevance to the topic of this report is the use of audio feedback[2,3] as reviewed recently by Middleton and Nortcliffe[4]. These studies have shown that use of the voice can significantly improve the effectiveness of feedback. Intonations in the voice can often be much clearer in emphasising key messages to the student and are also perceived by the student as being more personal and supportive than just written comments. In this report we present our findings from a pilot study conducted by the author on the use of screencasting to provide feedback to chemistry students on project reports and tutorial/workshop questions. This approach is shown to lead to feedback which is perceived by the students to be effective and highly personal. Based on our experience we also demonstrate an effective method of constructing and delivering such screencasts that requires no significant extra work from the tutor as compared with more traditional approaches.

Methodology

Tablet PC

The Tablet PC contains a pen that can be used to write or draw on the laptop screen using digital ink. The Tablet PC used by the author is a convertible Tablet where the screen can be rotated to convert from a normal laptop to a flat screen for writing purposes. Digital ink is available in a variety of colours and it can be easily modified or erased. While initially it can be difficult to write clearly on a computer screen, it is similar to writing on an overhead projector and with practice the author has found that he can write more clearly on the Tablet than on paper. In addition a variety of writing styles and colours are available simply by clicking on an icon. Microsoft Word has an inking option available for Tablet PCs allowing text to be written anywhere on the document and saved for future reference.

Screencasting

Screencasts are a digital video recording of your computer screen activity and usually include synchronised audio commentary. Essentially they are equivalent to letting somebody look over your shoulder to view your on-screen activity while you provide a running commentary. You can limit the recording to a specific program e.g a Word document or you can define the part of the screen that you wish to be recorded. You can also record a web camera image of yourself to accompany your presentation. There are a number of software products, both freeware and commercial, which allow you to record screencasts. The most popular, and the one used in this work was Camtasia Studio. Screencasts should be distinguished from Podcasts which generally refer to audio-only files which can be downloaded in a variety of formats. As mentioned in the introduction audio feedback using podcasts has been reviewed by Middleton and Nortcliffe[4]. In a physical science subject such as chemistry, where illustration and visualisation plays such a significant part, audio-only podcasting has limited potential for feedback, whereas a screencast combining graphic and dynamical illustration abilities in addition to audio commentary is ideally suited to the subject.

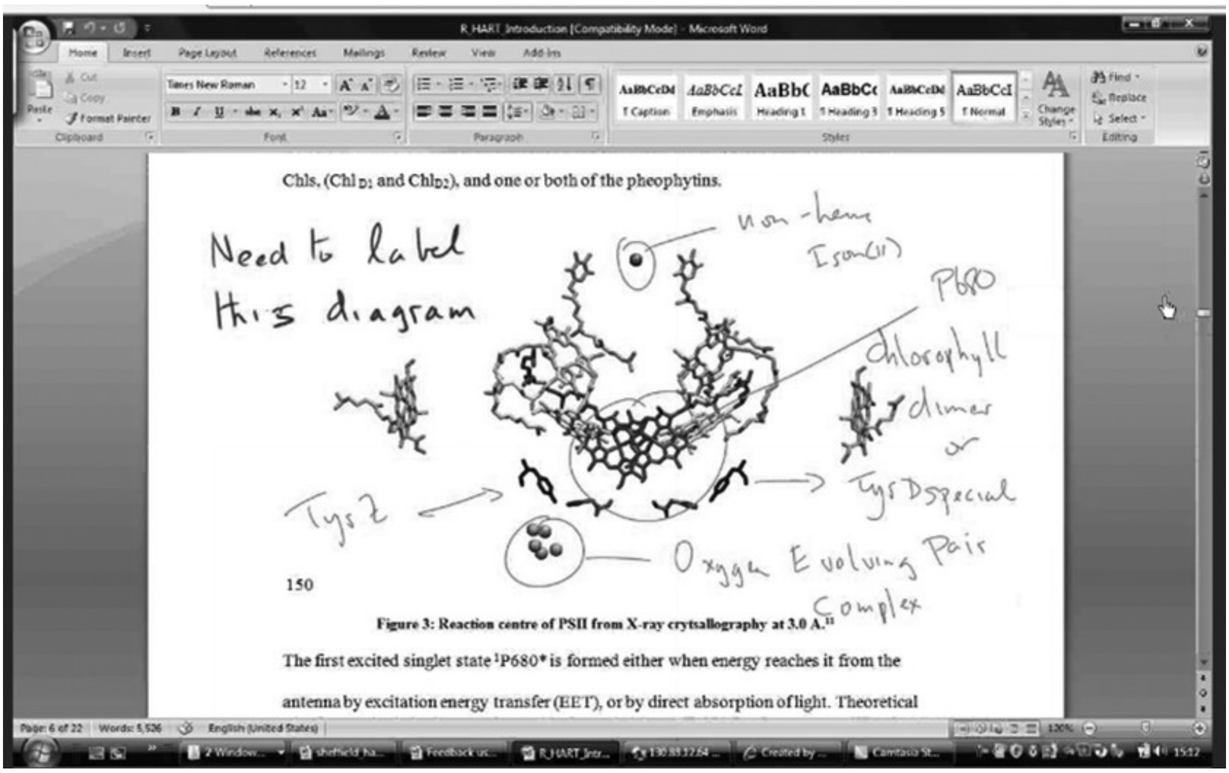

Figure 1: Snapshot of screencast feedback on a project report illustrating annotations inserted using Tablet PC. The document was submitted by the student as a Word document. Audio explaining annotations would accompany visual

Results

The use of screencasting feedback was piloted by the author on two main feedback areas of the chemistry curriculum at the University of Manchester. As part of their final year, MChem students are required to complete a final year research project and write an interim and final report. A group of students is assigned to each supervisor at the start of the final academic year. The interim project reports midway through the project are examined by the supervisor. Feedback is traditionally given in the form of a written proforma report on the submitted work. The report is submitted both electronically and in paper format. In the last academic year the author has returned screencast feedback on these reports to his students. The electronically submitted document is read onscreen and using the inking facility provided by Microsoft Word the document is annotated with specific corrections or suggested changes using a Tablet PC. After this initial reading of the document a screencast is recorded where the document and the suggested changes/improvements are summarised by the author. The student reports can be up to 40 pages long so this procedure of first reading and initially correcting the report permits the tutor to provide a short specific screencast report to the student usually lasting no longer than 5-10 minutes. The author saves the screencast in an Adobe Flash format (.swf) which can be viewed in any web browser. A wide range of other video formats are available but this has been found to be suitable for this current project. A screenshot from such a report is illustrated in Figure 1. The screencast and the annotated report are then returned by e-mail to the student.

The work involved for the tutor is essentially the same as that involved for a more traditional feedback using a proforma. For the students this sort of feedback was very popular and preferred to the more traditional approach. Typical comments were:

> *" I really found the screencast useful. It was much better than reading a form where I often feel the same comments are made to all students"*
> *"Ideal way to return feedback. It feels very specific to my needs and I can view it when or as often as I like"*

The second use of feedback screencasting using a Tablet PC was for a 1st Year tutorial group. Traditionally, example questions are supplied each week by the unit lecturer for the students to complete prior to the tutorial meeting. The answers are submitted prior to the tutorial meeting where they are marked by the tutor and returned with comments to the students at the tutorial. The tutorial time is usually used to review the answers to the problems and discuss generic problems raised. Although students can supply word-processed answers, this is not a requirement and answers are usually handwritten. In the pilot project students were asked to scan their handwritten answers and insert them as image files into a word-processing document such as Word. Most were quite adept at this and for anybody who was unable to do this I agreed to scan their handwritten answers if submitted by the given deadline. For a larger cohort of students this, if necessary, could be done using secretarial help. The number of questions to be completed by the students is generally 4-5 so in this case the screencast was usually ran on opening the file received by e-mail from the student. As illustrated for the coursework example above, annotations and suggestions can be inserted on the answers using the inking facility of the Tablet PC, all being synchronised with audio commentary. A screenshot of such feedback is shown in Figure 2. The screencast was saved in Adobe Flash format and returned to the student using e-mail. At the tutorial meeting time the students had already received screencast feedback on their work individually and the tutorial time could be used to cover other areas of the course or specific difficulties raised by the students. In many cases students questioned even the need for a full-length tutorial as they had already received individual, personalised feedback

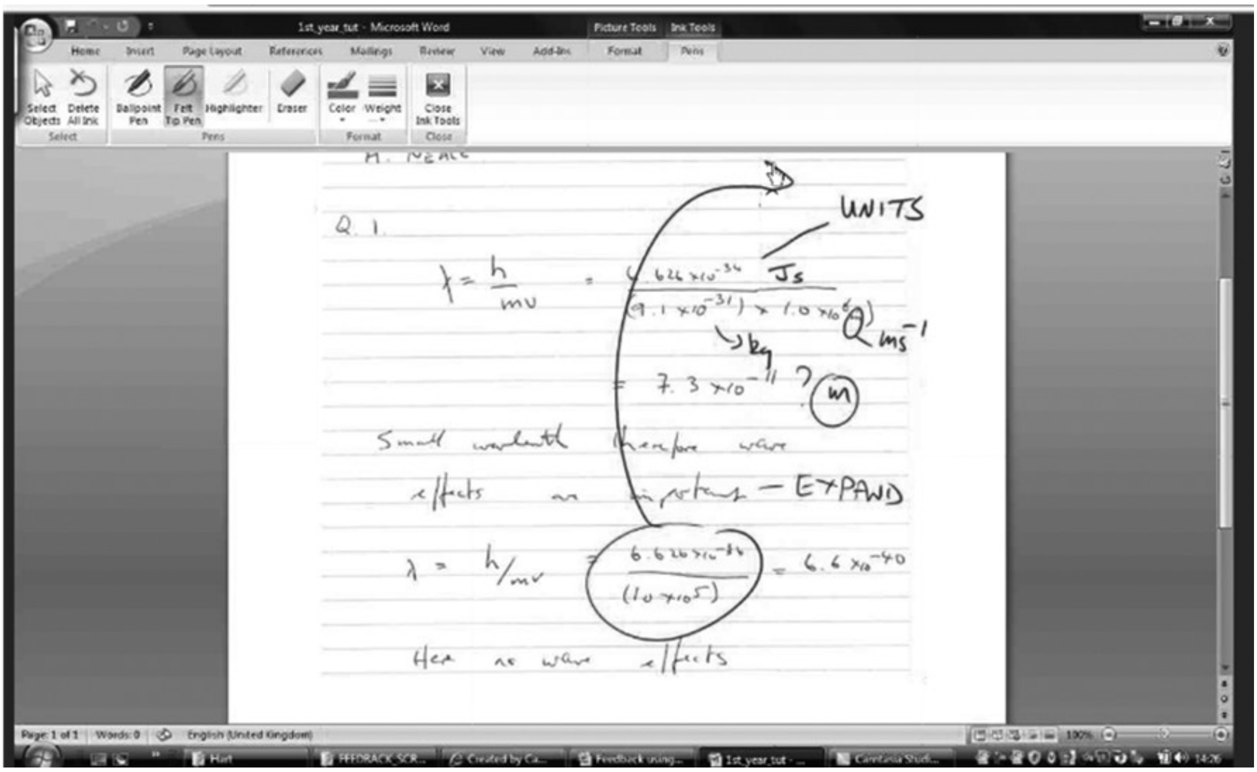

Figure 2: Snapshot of screencast feedback to student answer to tutorial question in physical chemistry. Student has handwritten answer and pasted scanned image into a Word document which is submitted electronically. Tutor annotations using a Tablet PC are shown and are accompanied by an audio commentary on the screencast

on their submitted answers. As for the first example, no significant extra time was expended in using screencast feedback compared with the traditional format, indeed as most of the face to face tutorials were shorter in duration the tutor time required was actually less. Students were universally favourable in their reaction:

> *"quite a nice way of marking instead of just red ink comments and talking explanations are so much better and encouraging"*
> *"simple things like commenting on how I put my answers together and how my untidiness in presentation can lose me marks are so useful"*
> *"sometimes its difficult to get what is meant by written comments, having the voice as well makes it so much more understandable"*

Often written comments, either on the student work or in a form, can be misinterpreted... The accompanying voice can be used to ensure that corrections and suggestions for improvement are constructive in nature and lead to enhanced future performance.

Discussion

As mentioned in the introduction it is often a lack of the personal or individualised "feel" that students most dislike about university feedback. Advances in communication need to be exploited by tutors to provide a personalised aspect to student feedback. Here we have shown how screencasting feedback can be effectively used to achieve this. On-screen annotation synchronised with the audio commentary is facilitated by use of a Tablet PC. An alternative approach would be the use of Word's review and comments facility with typewritten annotations. This is much less flexible than pen annotation and it would be difficult to achieve the annotation produced in Figures 1 or 2 with this facility. Many lecturers are traditionally used to writing comments in ink and the Tablet PC allows this. In the author's opinion pen annotation feels more natural and quicker to perform in particular while providing commentary at the same time. In some cases it may well be of benefit to combine both methods.

The power of the voice to convey the emotion of the tutor is quite important in our approach. Often written comments, either on the student work or in a form, can be misinterpreted and have negative connotations for the student. The accompanying voice can be used to ensure that corrections and suggestions for improvement are constructive in nature and lead to enhanced future performance. In addition the screencast provides the student with a unique opportunity to hear the tutor reflect on his/her work and make suggestions for improvements. Even compared to meeting each student on a one-to-one basis, there are some unique benefits for screencast feedback. Part of this arises from the opportunity for the student to hear the tutor reflect on the submitted work. This type of reflection is more difficult in a face to face meeting. In addition students often find one to one meetings with tutors quite daunting and can be very nervous as their work is discussed. As such they may find it difficult to relax and concentrate on the comments of the tutor. The screencast approach where the student can listen and see the tutor's comments in their own time and as many times as necessary alleviates this. Of course the screencast is a one way interaction and the student cannot question or ask for clarification of the tutor's remarks. However is always possible for the student to contact the tutor via e-mail or personally to clarify anything covered in the screecast feedback.

It is important to point out, from the tutor viewpoint, that once the technological aspects are mastered, the time taken to deliver feedback in this manner is not any different to that expended in more traditional approaches. Learning to record a screencast is in the author's opinion no more difficult than mastering a presentation package such as PowerPoint. Screencasting is used by the author in other areas of teaching such as lecture capture[5] and molecular modelling demonstrations[6]. The author has also found it useful in providing advice and feedback to postgraduate students conducting research projects. It is also possible to use this approach to provide more generic feedback to a whole cohort of students perhaps in addition to the personal approach focussed on in this report.

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Sharing learning outcomes in chemistry teaching at HE level: beneficial or detrimental?

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Abstract

The sharing of explicit learning objectives and/or learning outcomes is considered to be good practice in schools, with OFSTED observation criteria indicating that this is a pre-requisite to a good or outstanding lesson[1]. Such practice does not appear to be widespread in chemistry teaching at HE level. Whilst a statement of aims/objectives/ outcomes can normally be found in the documentation accompanying any given unit of teaching, these are typically in a less student-friendly format than those used in school, or are too vague to be useful. At the same time, many lecturers do communicate aims at the start of a lecture, but there may be scope for doing this in a more effective way. The extent to which students are exposed to 'learning outcomes' varies greatly from institution to institution, discipline to discipline and from teacher to teacher, and as such it is difficult to discern the best approach.

This article presents some background on developments at pre-university level that have influenced practice in this area, and outlines the findings of a research project carried out in the School of Chemistry at the University of Southampton. The project probed the views of staff and students regarding the usefulness of learning outcomes. Several different approaches to sharing learning outcomes with first year students were trialled and evaluated during the course of the 2010-11 academic year. This work is part of an on-going initiative which aims to identify effective methods to support students in becoming independent learners when making the transition to university, and to improve retention rates.

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Background

Learning outcomes are specific, concise statements describing precisely what students are expected to be able to do at the end of any learning activity. Watson succinctly defined a learning outcome as 'something that students can do now that they could not do previously...as a result of a learning experience'[2]. Guidance regarding the use of learning outcomes at HE level has been provided by Overton[3], who noted that they should:

- be written in the future tense
- identify important learning requirements
- be achievable and assessable
- use clear language easily understandable to students

It is worth noting that there is some scepticism among practitioners regarding the true value of learning outcomes, and particularly the additional bureaucracy entailed[4], and these reflect the concerns expressed by some staff at HE level. As such, there is clearly value in carrying out research in this area to ascertain the value that students place on learning outcomes, and to find out how they are used in self-study.

The investigation into the value of sharing learning outcomes with students was carried out by a BSc student as part of a final year research project in chemical education[5]. Learning outcomes were written in a collaborative process between the student and the lecturers using the guidance of Bloom's Taxonomy[6,7]. After receiving staff approval, these were shared with students in different ways in an attempt to identify the most effective approach. Student feedback on the use of learning outcomes was obtained from student interviews and a survey conducted using electronic voting systems. The overall aim of the project was to find out if shared learning outcomes are beneficial to student learning, with the evidence collected then being used in staff discussions regarding the future development of the course.

In considering the findings described below, it should be noted that, in an ideal world, the writing of learning outcomes should be the first stage in the creation of any unit of teaching. As such, it is acknowledged that the project described herein goes about things in a 'back-to-front' fashion. It should be noted, however, that all staff were very clear in their own minds about what it was that students were meant to learn from a particular lecture and this had always been communicated in the introduction to the lectures and in a summary at the end. An additional aim of the project was to find out if there was a more effective way of communicating this information to students.

Learning outcomes for lectures in semester one

The semester one taught material formed the basis of an exercise which would probe the views of staff about learning outcomes and would consider a process for sharing them with students in the future. As such, the intention was not to share learning outcomes with students during teaching in semester one. Learning outcomes were compiled into a master document for detailed analysis over the Christmas break. It should be emphasised that this study considered learning outcomes relating to specific lectures, rather than overarching module learning outcomes which are more universal in nature.

Figure 1 shows a list of learning outcomes taken from one organic chemistry lecture which took place in Semester 1. It is interesting to note that there are 10 discreet learning outcomes in this list, which is a significant increase on the 3 or 4 that would typically be covered in an A-level lesson.

After a favourable response from the staff involved, the learning outcomes for all lectures that took place in semester one were made available to students for download from the online Blackboard course on their return to Southampton after Christmas. As teaching had finished before Christmas, students would only be able to use the learning outcomes to support their revision. The students were also informed that an investigation into the effectiveness of sharing learning outcomes was being conducted, and that their views as volunteers would be sought for the evaluation of the project.

Learning outcomes for lectures in semester two

In order to allow the project student enough time to complete the evaluation process, learning outcomes were only written for a small number of lectures in semester two. One lecturer who was delivering 9 lectures in physical chemistry agreed to take part in this part of the investigation, which looked at different approaches to sharing learning outcomes with students. It was originally intended that three approaches would be taken:

(a) Learning outcomes shared after each block of lectures (there were three blocks of three lectures in this part of the unit).
(b) Learning outcomes shared after each lecture.
(c) Learning outcomes shared before each lecture.

Figure 2 shows the points at which learning outcomes were shared during the sequence of lectures. Due to time constraints, the learning outcomes for both of the first two blocks of three lectures were shared at the end of each block

By the end of this lecture students should be able to…

Define Huckel's rule (aromatic molecules are cyclic planar molecules that have fully conjugated π-systems and contain (4n+2) π-electrons) and explain how benzene obeys this rule.

Draw and explain the structure of benzene including the hybridisation of orbitals and the planar delocalised π system.

Describe the high stability of aromatic molecules; activation required for electrophilic aromatic substitution and a catalyst is used during hydrogenation.

Write the mechanism for the addition reaction of bromine to ethene; including the structure of the bromonium ion intermediate.

Recall that for electrophilic aromatic substitution benzene must be activated by a Lewis acid and that the reaction involves the π electrons.

Draw all resonance structures to show delocalisation in the intermediate cation formed during electrophilic aromatic substitution.

Explain the role of substituent effects in determining the rate of electrophilic aromatic substitution at the para- position (e.g. in anisole) in terms of activation energy and stabilisation of the transition state by the MeO- group (+M and -I effect).

Recall and describe the structure of aromatic heterocyclic compounds; pyridine, pyrrole and furan; all planar with conjugated π systems containing 6 electrons.

Compare and explain the basicity of pyrrole and pyridine; pyridine has the lone pair orthogonal to π system and protonation destroys aromaticity, pyrrole has its lone pair conjugated into the π system.

Describe the acidity of cyclopentadiene; i.e high acidity due to the stable aromatic anion conjugated base so has a low pKa value and is easily deprotonated.

Figure 1: Learning outcomes relating to a first semester organic chemistry lecture

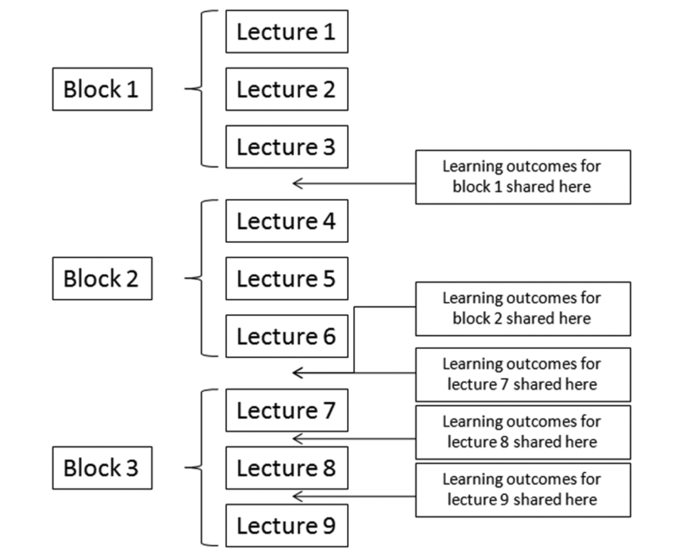

Figure 2: When learning outcomes were shared during the lecture course

(i.e. after lecture three and lecture six). This meant that it was not possible to investigate approach (b), as it was deemed that approach (c) would provide more interesting data and this was used for the lectures in block 3. In line with this, the learning outcomes for lectures seven, eight and nine were made available after each of the preceding lectures had taken place. In all cases, hard copies were issued during lectures, with material also available in electronic form on Blackboard. Students were kept informed by regular announcements during lectures and by e-mail.

The staff view of learning outcomes

Although staff were happy at the outset with the idea of a project student writing learning outcomes for their lectures, they had been largely unconvinced about the value of doing so. Some staff felt that a list of explicit learning outcomes was too much like a 'syllabus', which could be seen as 'spoon-feeding' or may actually place a boundary on students' learning. It was therefore interesting to note the very positive response of all the staff on the first occasion that they read a set of learning outcomes for one of their lectures. They were all impressed with the simplicity of the statements which concisely outlined the key learning points for students, while a lengthy list of learning outcomes was reassuring in showing just how much material is covered in a typical lecture. As mentioned previously, all staff consented to making the complete list of learning outcomes available to students for use in their revision, and they all expressed an interest in finding out more about how students would use them and what the benefits might be.

The student response to shared learning outcomes

Quantitative evaluation

At the end of the series of lectures (semester two), a survey of 91 first year students was conducted using electronic voting systems. The data collected showed that two thirds of students had made use of the learning outcomes in some way. The answer to the question posed in the title of this article is indicated in Figure 3, which shows that a large majority of students who had looked at the semester 1 learning outcomes felt that doing so had been beneficial to their understanding. While most students used the learning outcomes individually, 10 students indicated that they had used the learning outcomes in groups, which was seen as a positive result.

Student views regarding the two different approaches to sharing learning outcomes that were trialled in semester two are shown in figures 4 and 5. It is clear that students were much more likely to interact with the learning outcomes in a meaningful way in their study after lectures rather than beforehand. A small number of students indicated that sharing learning outcomes beforehand could have a detrimental effect, perhaps by giving an impression that there would be no point in going to lectures if the content was already known.

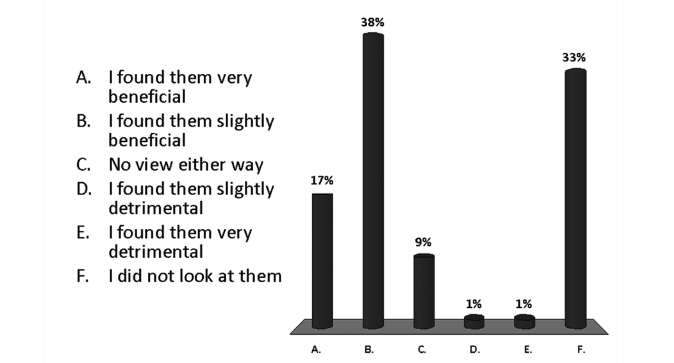

Figure 3: Answers to 'Did you find the learning outcomes given for Semester 1 beneficial to your understanding of the CHEM1018 course?'

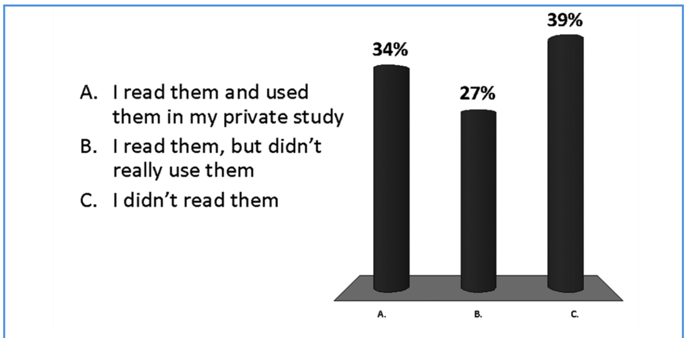

Figure 4: Answers to 'When we gave you the learning outcomes at the end of the unit of lectures (parts 1 and 2), how did you use them?'

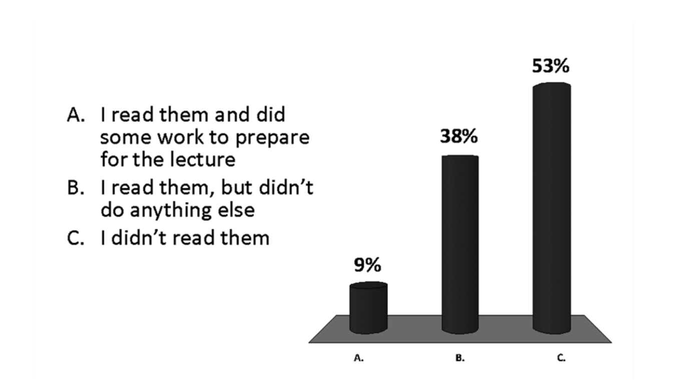

Figure 5: Answers to 'When we gave you the learning outcomes before each lecture, how did you use them?'

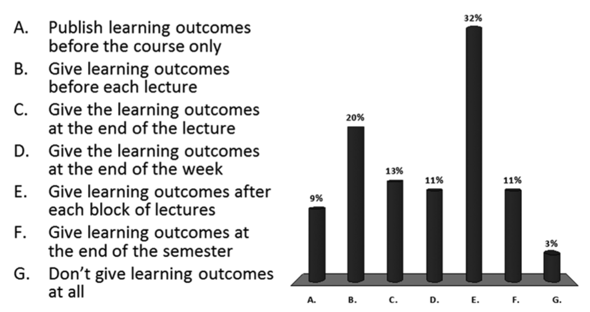

Figure 6: Answers to 'What would be the most effective strategy for learning outcomes?'

Finally, figure 6 shows the students' views on when is the most appropriate time to share the learning outcomes. Although there is a spread of opinions, the most commonly held view was that learning outcomes should be shared at the end of each block of lectures, although a significant number also saw value in them being shared before. Of course, if the latter approach is taken, then the learning outcomes are still available for everyone to use at any point afterwards, and this answer is perhaps more a reflection of when students would be likely to pay attention to the learning outcomes.

Qualitative evaluation

Six students who had used the semester one learning outcomes during their study were interviewed at the start of semester two. Follow-up interviews were conducted with two of these individuals towards the end of the semester.

One student mentioned that he was *"intimidated by the fact that there were so many"* learning outcomes, showing that our initial concerns about the sheer number of learning outcomes were justified. However, this student indicated that he had gained confidence by working through the list of learning outcomes with some of his peers, which wasn't necessarily expected. Another student felt that it was useful to see the learning outcomes as this prevented her from *"underestimating the amount covered in lectures".*

Some students reported using the learning outcomes as a checklist to go through after revising a particular topic, with one describing a 'traffic lighting' system to indicate their confidence level for a particular item, which was beneficial in highlighting key areas to focus on in subsequent study. Another student remarked that it is possible to *"get lost with lecture notes and the learning outcomes can guide you through what you really need to know"*. A further comment was that learning outcomes *"clarified points well and having them to look back on to summarise content is excellent".*

Some comments were particularly interesting in showing that the learning outcomes were helping students to 'scaffold' their learning, with one noting that the exercise *"allowed me to see how all the learning outcomes were connected".* Another student expressed that the learning outcomes would be beneficial *"by showing how one piece of knowledge, once learnt, would assist me later on in the course".* This individual also *"linked certain learning outcomes to parts of the textbook for easier learning",* showing that shared learning outcomes can support students in their self-study.

As indicated in the previous section, the majority of students did not interact meaningfully with learning outcomes that were shared prior to lectures. The main reason given was that students found that the learning outcomes for material they hadn't seen already were difficult to interpret, meaning they preferred to look at them after the lecture instead.

Conclusions

The evidence shows that students do see value in shared learning outcomes, with a range of different benefits described. The fact that students reported that looking at learning outcomes after a block of lectures helped them to summarise the key learning and to see how different concepts link together is a very positive result, as these are key independent learning skills that many of our incoming students struggle to come to develop. An additional benefit that hadn't been predicted was the fact that the learning outcomes were used to facilitate peer-assisted learning. The results of this project have also helped to change staff perceptions of learning outcomes, and will lead to changes in the delivery of the first year course at Southampton, showing that such final year projects really can have an impact on teaching at HE level.[5]

Whether or not detailed learning outcomes should be written and shared for all lectures throughout a degree programme is a question that should be considered carefully. This is certainly beneficial early on, when the sheer volume of material encountered is so much greater than that covered in a typical school lesson. Also, at school, the onus is on the teacher to ensure that students achieve the learning outcomes, while at university, the responsibility moves to the student. Explicit learning outcomes might help students to make the transition to university learning more effectively by clarifying exactly what they are learning. This might help to improve retention rates, with students potentially being less likely to 'take fright' in the early part of their degree studies. There is certainly evidence from the interviews that students took some reassurance from using learning outcomes in their studies.

However, learning outcomes should be used with some caution. One student stated that he liked them because "I didn't waste time learning things that I didn't need to know". This should give pause for thought, as it would be a shame if students were discouraged from reading around their subject and finding topics that they are really interested in, choosing instead to simply learn things that might come up in an exam. Such a situation flies in the face of what 'reading for a degree' is all about, and would rightly be considered to be detrimental to the student learning experience. It may therefore be beneficial to share learning outcomes which are less explicit as students advance through their studies, encouraging them to develop their own interests and take control of their own learning, while also achieving what they need to in order to graduate with the degree they want.

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Staff and student opinions of the inclusion of practical work in higher education chemistry courses in England: what are the perceived objectives and outcomes?

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Abstract
Practical work is seen as an essential part of science courses. However, practical work is very resource intensive and in the current HE environment, in which academics will inevitably find themselves teaching more students with fewer resources, it is important to justify the cost in terms of educational benefit and so the objectives must be clear.

This report describes the results of a survey of students undertaking chemistry undergraduate courses and staff in Higher Education chemistry departments in England. These surveys aimed to ascertain the range of practical work being carried out, alongside staff and student opinions of practical work. It also examined the reasons why practical work is included in undergraduate courses and what students take away from participating.

Background
Chemistry is studied in almost 40 universities in England[1]. Within chemistry courses practical work is a key component with between 6 and 12 hours a week of students time being spent in the laboratory through a mix of timetabled and project work. With this high investment of time, it is essential that the learning from this experience is worthy of the input.

Practical work is often claimed to be essential to a chemistry course with little justification of why this is so[2]. This study aims to gain an insight into why staff and students think practical work is included in chemistry courses. It also aimed to examine what students actually take away from practical work and if this matches the objectives.

This study aims to gain an insight into why staff and students think practical work is included in chemistry courses.

Types of practical work
Domin discusses the different types of practical work style in use (expository, inquiry, discovery and problem based)[3]. These types vary depending on the outcome (pre-determined or undetermined), the approach (deductive or inductive) and procedure (given or student generated) (Table 1).

Table 1: Characteristics of the different types of practical work. Adapted from Domin[3]

Type	Approach	Procedure	Outcome
Expository	Given	Deductive	Known
Inquiry	Student-generated	Inductive	Unknown
Discovery	Given	Inductive	Known
Problem based	Student-generated	Deductive	Known

These different types of practical work use and develop different skills. They may also be suited to achieve different objectives[3] and be used at different stages in a university degree. Within this project, students have been asked to identify the type they predominately carry out and see if this relates to their opinions and experiences of practical work.

Expository
Within an expository practical students follow given instructions to obtain an outcome known by the lecturers. Expository activities can be followed by large numbers of students at the same time, with little set up in terms of putting the experiment together and running costs[2]. As the procedure is given, students may follow it without understanding the procedure[4] but due to its recipe-style formula, students can concentrate on learning basic experimental technique without getting distracted by detail limiting the strain on working memory[6]. This makes it ideal for large first year classes who need to build experience and confidence.

Inquiry
Inquiry or experimental practicals involve students generating their own methods and procedures. The outcome is unknown and students must come to a conclusion based on their work. With this approach students are responsible for the direction they take. For this type of activity it is important that the students are prepared or they may not reach the desired conclusion[7]. They need appropriate background knowledge which they can build on[8]. It places greater emphasis on the scientific process, rather than science content, which may lead it to being criticised as the amount of science content a student can cover will be reduced[9].

Inquiry activities closely mimic real research and give students ownership of their work and findings[2]. It is difficult to implement with large numbers of students, and requires much greater supervision as students are following their own plans. It relies on students having background knowledge and competent practical skills and also requires the student to process a lot of information. Therefore it may be more suitable for small numbers of final year students who have the required experience.

Discovery
In discovery practicals, students are given some background information and must develop their own experiments. Students are guided towards discovering the known outcome. The aim is for students to discover a concept for themselves and focuses more on interpretation of results, rather than experimental design as is seen with inquiry[2]. Again it is more time consuming as careful guidance is needed to ensure students reach the desired outcome. There are also arguments that student are unable to achieve outcomes if they are not known to them[3].

Problem based learning
Problem Based Learning (PBL) practicals involve students working in groups to solve real-life problems. They are given the problem, must find background information and procedures, and generate their own experiments. These types are usually put in a real life context to give more relevance[2]. Students are reported to have greater engagement with this type of practical work and appreciate being able to learn from their mistakes[10]. This is also time consuming to set up and needs close supervision as students can chose their own direction[5]. Within this, students use existing knowledge in a new situation, so this is not useful for adding to a student's knowledge base but allows students to show their ability to apply understanding.

Objectives of practical work
There has been much discussion in the literature about the objectives of practical work. Kirschner and Meester reviewed literature on practical work to try to define the overall objectives[11]. They found 120 different objectives, which they classified into eight general objectives:

- To formulate hypotheses
- To solve problems
- To use knowledge and skills in unfamiliar situations
- To design simple experiments to test hypotheses
- To use laboratory skills in performing experiments
- To interpret experimental data
- To design clearly the experiment
- To remember the central idea of an experiment over a significant long period of time

Carnduff and Reid outlined three broad areas for the inclusion of practical work[12]:

- Practical skills
- Transferrable skills
- Intellectual stimulation

Reid and Shah build on this by stating thirteen reasons for including practical work[13]:
Illustrating key concepts

- Seeing things for 'real'
- Introducing equipment
- Training in specific practical skills and safety
- Teaching experimental design
- Developing observational skills
- Developing deduction and interpretation skills
- Developing team working skills
- Showing how theory arises from experimentation
- Reporting, presenting, data analysis and discussion
- Developing time management skills
- Enhancing motivation and building confidence
- Developing problem solving skills

From these three examples of the aims of practical work, some themes recur. It is clear practical work is seen to develop chemistry practical skills. It also is seen to illustrate learning elsewhere and develop a range of transferable skills. What is not discussed is how students view practical work and if they actually achieve the aims set for the practical work. There is evidence to suggest that practical work does not achieve the learning expected[4]. Therefore it is important that whatever the aims of practical work are, suitable teaching methods are employed to ensure these are achieved.

Perceptions of practical work
Hanif *et al.* carried out a study of the views of practical work used in undergraduate physics courses to identify if practical work provides the desired outcomes and so is worth the costs involved[14]. 143 undergraduate students, mainly in the first year, with a small number form the second and third years,

were surveyed. The students were studying at a Scottish university, so those in the first year may be taking physics as part of a degree in another subject. The survey asked students about their experiences in laboratory work in physics through a series of statements with which they indicated their level of agreement, on a five point likert scale. Students overwhelmingly were found to prefer to have written instructions (76% agreement), and a large proportion (47%) agreed that they followed instructions without understanding what they were doing, this was supported by students agreeing that they only understood what they were doing when writing up afterwards (26% agreeing and 36% unsure). They saw the educational benefits of practical work, with agreement that the experiment linked to theory and that discussion in the laboratory enhances their understanding of physics. Students identified physics as a practical subject and placed importance on this being why practical work is included. They also identified using practical work to illustrate theories and for development of practical skills as being important. This research has looked at whether students in chemistry have similar opinions.

Kirschner and Meester used a survey comprising of 63 learning objectives of practical work[15] as compiled by Kirschner and Meester[11]. Students in the natural sciences were asked to indicate before a practical activity if they expected to encounter each of these objectives in the practical activity. After the practical activity, they were asked to indicate from the same list of objectives, which they encountered. It was found that student expectations of practical work influences what they encounter regardless of what the intended objectives were. They found that if students are not aware of an intended objective then they will not achieve the set objective. Also students will encounter objectives they expect will be present, even if they are not present in the practical work. Therefore if staff and students have different opinions of the objectives of practical work, students may not achieve the objectives defined by staff.

Methodology

Two complimentary surveys were designed and distributed in early 2010 to collect staff and student's opinions of practical work; one for students currently studying for a degree in chemistry and the other for staff involved in the delivery of these courses. Nine English universities with known contacts were identified and the surveys sent via email, as a link to an online version on Bristol Online Surveys (BOS). These contacts were asked to distribute the staff and student surveys to others in the department. The universities targeted were a mixture of Russell group, 1994 group and other types of university, three of each type being selected. The surveys were also distributed via email lists to widen the sample.

The surveys were designed to build upon the literature. Belt concentrated on asking members of staff in chemistry departments to list their top three reasons for including practical work in chemistry courses[16]. Belt asked staff members in a variety of chemistry departments to list the purposes of practical work and he matched these to the 13 reasons listed by Reid and Shah[13]. A similar question was included.

Questions were also included based on the work of Sneddon *et al.* who asked undergraduates in physics about their perceptions and opinions of practical work[17]. Student respondents were asked to identify the type of practical work they carry out and which they would prefer to be carrying out based on Domin's four identified types; expository, inquiry, problem-based and discovery[3]. Staff were asked a similar question to identify which type they think students should be following.

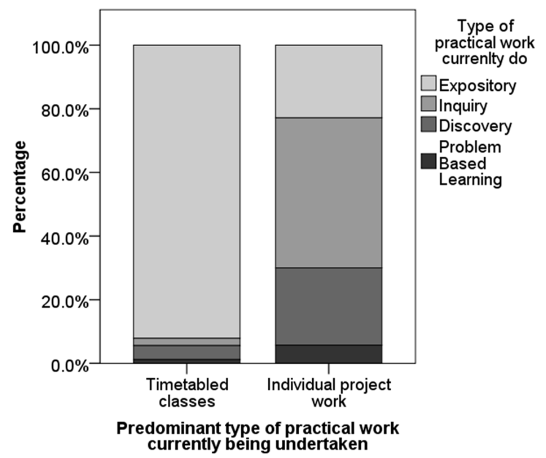

Figure 1: Type of practical work students currently do according to the scheduling of practical work currently being undertaken

Respondents were asked to identify the top three reasons they think are the most important for including practical work from a supplied list, comprising the 13 reasons identified by Carnduff and Reid[12] and discussed by Reid and Shah[13].

Overview of data

The percentage response rate from students from each of the nine targeted universities varies from 1 to 21% with the average being 10%. There is a wide range of responses from students from different universities and in different academic years; the data may be unrepresentative of the wider population so any analysis must be treated with care.

A total of 528 student responses were obtained from English universities. The responses represent 12 different universities, mainly Russell group universities (446 responses), and some from non-Russell group universities (82 responses). There is a small majority of respondents studying for an MChem (58%). The responses are from an almost 50:50 split of males (50.5%) and females (49.5%). This is consistent with national data which shows in 2005/6 the proportion of males to females entering chemistry courses was 56:44[1]. The majority of the responses are from students between the ages of 18 and 21 (89.3%). The majority (56%) of student respondents plan to follow a career directly related to chemistry, with 11% not planning to follow a career related to chemistry, and 33%, have not yet decided their career plans.

Only 46 responses were obtained from members of staff in English universities, representing 22 different universities. Of these, seven of the universities correspond to the universities represented by the student responses. This is a wide range, with only a few responses from each of the universities. The responses comprise 17 (37%) from Russell group universities, and 29 (63%) from non-Russell group universities. These are very small numbers of responses so analysis will simply be descriptive, and not statistically significant of the wider population.

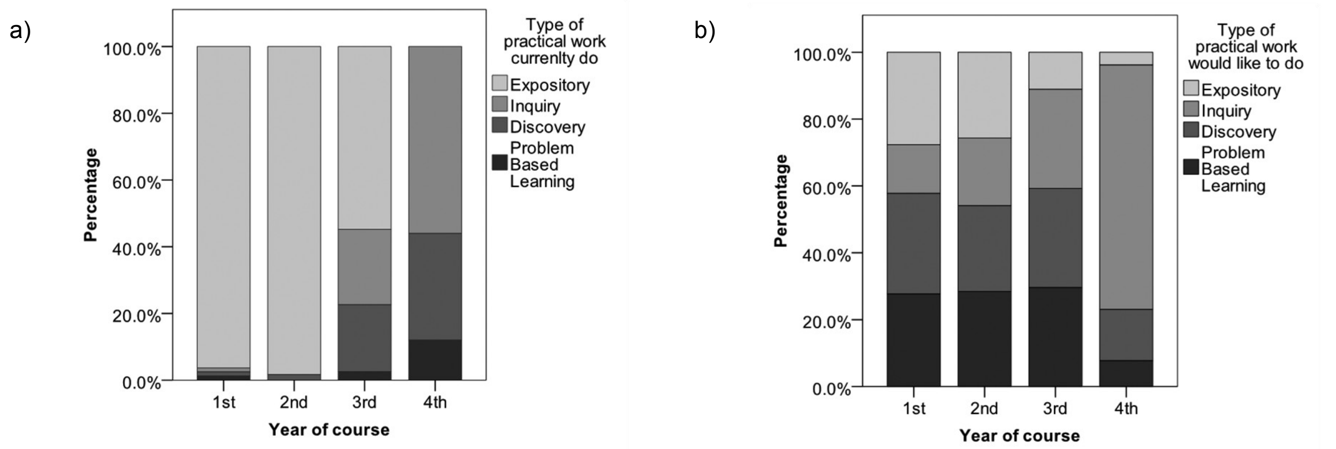

Figure 2: Type of practical work students a) currently do and b) would like to do, according to year of study

31 of the staff respondents (68.9%) are male and 14 (30.4%) female. This gender distribution is a little higher towards number of female respondents compared to the actual distribution found in chemistry departments in 2008, 80% male, 20% female[1]. The job titles given by the respondents cover the full range of job choices given in the survey, with the greatest number of responses being from senior or principal lectures.

Types of practical work carried out
On the surveys staff and students were given definitions for different types of practical work based on the four types Domin suggested are present in practical work (expository, inquiry, discovery, problem base learning)[3]. Student respondents were asked to identify what type of practical work they currently undertake and which they would like to carry out if they had the choice. Those students who are currently undertaking timetabled practical classes are predominately following expository procedures (Figure 1). This is traditional recipe style practical work that is widely carried out in undergraduate chemistry courses[2]. A small number of students identified the practical work currently being carried out as one of the other types. It is possible that these students mis-interpreted the definition or the question, but this is not clear and is a limitation of the survey data.

Those carrying out individual project work identified a range of types of practical work being followed (Figure 1). The predominant type followed is inquiry (47%) which describes a research project in which students devise and carry out their own experiments. 24% of students carry out discovery type of practical work. However, 23% of those students carrying out an individual project identify the type carried out as expository. This is unexpected as this would imply the students are carrying out experiments given to them to determine an outcome known to the lecturer. This type would not be normally expected to be associated with project work and could be due to the respondents misreading or misunderstanding the question, or perhaps is their interpretation of the practical work carried out.

Student respondents indicated that the majority of practical work carried out in years 1 and 2 is expository (96% and 98% respectively) (Figure 2a). This suggests that for the first two years of study, a recipe style of practical work is relied upon. Staff respondents support this, as they state it is the only type carried out in the first year and the predominant type in the second year. Staff indicate that if they could change the type of practical work followed, the majority would chose expository for first year students. This type is easy to run with a large number of students as all students will be following the same experiment[2]. It is also perhaps easier for students with little practical experience to follow so would make sense for this to predominate[5].

A study by Meester and Maskill analysed the content of first year chemistry practical manuals from 17 universities in England and Wales to determine the level of scientific inquiry covered[18]. They found that over 90% of the experiments analysed covered a low level of scientific inquiry, in which the

Table 2: Type of practical work indicated by staff being predominately carried in each year of study

	1st		2nd		3rd		4th	
	No.	%	No.	%	No.	%	No.	%
Expository	45	100	39	86.7	14	31.8	1	2.6
Inquiry	0	0	4	8.9	15	34.1	21	53.8
Discovery	0	0	1	2.2	14	31.8	13	33.3
Problem Based Learning	0	0	1	2.2	1	2.3	4	10.3
No. Responses	45		45		44		39	

aims and methods are given to the student, in other works they follow an expository method. It would appear that not much has changed since this study in 1995, with 96% of first year students still following expository type practical work.

Students in the third year of study indicated a greater range of practical types being followed (Figure 2a), with expository still being the predominant type (55%), so the majority of students are still carrying out traditional types of practical work. In the third year, 23% of students undertake inquiry, 20% discovery and 3% problem based. Some third year students, both MChem and BSc may be undertaking project type work which would support a range of types of practical work[1]. Staff respondents confirm that practical work in the third year is more varied (Table 2), with a roughly even split of expository, inquiry and discovery.

By the fourth year of study, students who responded indicate that expository based practical work is no longer undertaken (Figure 2a), which is confirmed by staff (Table 2). The predominant type now is inquiry (56% student response; 54% staff response) followed by discovery (32% student response; 33% staff response) and problem based (12% student response; 10% staff response). Students in the fourth year are those following a MChem programme and these students would be expected to carry out an extended project. From these responses these projects appear to cover a range of types, which all involve development of their own experiments. This indicates that by the fourth year, students have more freedom with the practical work they undertake.

Overall students indicated that the type of practical work they would like to carry out (Figure 2b) is quite different from what they currently carry out (Figure 2a). Students want to carry out less expository based practical work, with only 28% of first year students wishing to carry this out, compared to 96% who currently carry it out. The amount of students wishing to carry out expository practical work decreases with year, with 26% of second years, 11% of third years and 4% of fourth years.

By the fourth year, the majority of students would like to carry out inquiry based practical work (73%) which involves carrying out a research based project. This suggests that as students progress through the years they appreciate carrying out different types of practical work, perhaps as they gain more experience in basic techniques.

Staff also indicate that there should be less reliance on expository types of practical work in later years, with greater emphasis on inquiry and problem based. Due to the limitations of the data, it is not clear why this is so. These alternative types develop a wider range of skills and challenge students more[19]. Perhaps staff feel this is important for the development of the students. Inquiry and problem based are also more akin to the scientific process[2], and encourage students to connect new knowledge to old[7] which may be seen as an important aspect of practical work.

Objectives and outcomes of practical work

Both staff and students were asked to select the three most important reasons for including practical work into the chemistry course from a list of 13 (Table 3).

*Table 3 : The most important reasons selected by staff and student respondents for including practical work into the chemistry course. Student responses are also shown according to year of study. The top reason is highlighted in **bold**. The lowest rated reason is highlighted in italics*

	Percentage response					
	Staff	Students				
		Overall	1st	2nd	3rd	4th
	n=46	n=528	n=256	n=121	n=122	n=26
Developing deduction, interpretation skills	43.5	30.1	30.9	25.6	34.4	23.1
Developing observational skills	8.7	13.3	15.6	12.4	11.5	***3.8***
Developing problem solving skills	34.8	26.9	25.0	27.3	27.9	42.3
Developing team working skills	6.5	***7.0***	***9.8***	***5.0***	***4.1***	***3.8***
Developing time management skills	*4.3*	12.5	12.9	13.2	11.5	11.5
Enhancing motivation and building confidence	6.5	9.5	***9.8***	8.3	10.7	7.7
Illustrating key concepts	39.1	30.3	34.4	25.6	28.7	19.2
Introducing equipment	8.7	24.2	25.0	23.1	27.9	7.7
Reporting, presenting, data analysis and discussion	45.7	**41.3**	**36.7**	**44.6**	**46.7**	46.2
Seeing things for 'real'	26.1	24.2	26.2	26.4	19.7	15.4
Showing how theory arises from experimentation	17.4	34.7	36.3	38.8	28.7	23.1
Teaching experimental design	13.0	11.4	10.2	12.4	12.3	15.4
Training in specific practical skills/safety	**50.0**	32.0	26.2	29.8	40.2	**61.5**
To achieve Royal Society of Chemistry Accreditation	***4.3***	-	-	-	-	-

Only 46 staff responses were collected so the data may not be truly representative of staff views. Overall both staff and students have identified similar reasons for including practical work in chemistry courses. This implies that students have the same ideas about why practical work is included and perhaps are aware of the aims of practical work which staff intend them to achieve.

Within the student and staff surveys, the respondents were presented with a list of statements about how students experience practical work and what staff think students take from practical work, and asked to rate the statements on a five point likert scale. The agree and strongly agree, and disagree and strongly disagree responses have been combined to indicate those who responded positively to a statement and those who responded negatively, to give a simpler overview of the data (Table 4). Overall, the staff opinions about the student experience of practical work are very similar to those of the student respondents.

Reasons for including practical work

Both staff and students identify developing practical skills and scientific skills as the most important reasons for including practical work. *'Training in specific practical skills/safety'* was identified as the most important reason by staff, with 50% of the respondents choosing this (Table 3). Clearly, staff see practical work as being very important to developing practical skills, perhaps for students to be trained as future researchers or for their future careers[4]. 32% of student respondents identified this reason (third most chosen reason). Within practical work, students will use a variety of techniques throughout the course, so clearly they see this as an important aspect of practical work[2]. Students and staff reported that practical work skills are indeed developed (Table 4).

Training in specific practical skills/safety is identified as one of the top reasons by second, third and fourth year students (Table 3). However, first year students do not identify this as one of the top three reasons. Instead they identify illustrating key concepts as the third most important reason (34%), which is not identified by the other three years as one of the top three reasons. This perhaps suggests that first year students expect practical work to be used to illustrate chemistry covered elsewhere in the curriculum, and as the students progress through the years, they see this as a less important aspect of practical work. Practical work is often not linked to lectures leading to it being seen as isolated and unrelated[11].

Students reported that practical work develops a range of scientific and practical skills; including observational skills (82% agreement), and interpretation skills (72% disagree with the statement 'I do not develop interpretation skills during practical work'). The predominant type of assessment for practical work is writing up an experimental report[2]. Staff and students both recognise this as an important aspect of practical work. *'Reporting, presenting, data analysis and discussion'* was identified highly by staff (second reason, 46%) and as the most important by the student respondents (41%) (Table 3).

Table 4: Comparison of staff and student responses about the student experience of practical work. The statements have been modified to allow comparison of the staff and students responses

	Staff, n=46			Student, n=546		
	SA/A	**N**	**D/SD**	**SA/A**	**N**	**D/SD**
Helps learn	87.0	13.0	0.0	82.1	11.5	6.4
Illustrates key concepts	93.5	6.5	0.0	81.0	13.6	5.5
Rely on written instructions	75.6	20.0	4.4	43.0	24.5	32.4
Observational skills developed	76.1	19.6	4.3	82.2	14.3	3.5
Opportunities to write reports	97.8	2.2	0.0	80.2	10.6	9.2
No chance to work in teams	17.4	17.4	65.2	19.8	17.4	62.8
Time management skills developed	60.9	28.3	10.9	73.4	17.1	9.5
Increases motivation	67.4	28.3	4.3	59.9	25.0	15.1
Helps see things for 'real'	82.6	17.4	0.0	80.0	14.9	5.1
No opportunity to design experiments	56.5	23.9	19.6	68.4	14.7	16.9
Gain practical skills	100.0	0.0	0.0	98.2	1.7	0.2
Helps understanding of chemistry	93.5	4.3	2.2	78.7	12.9	8.3
Develop interpretation skills	87.0	8.7	4.3	71.5	19.8	8.7
Chance to problem solve	73.9	19.6	6.5	72.9	16.6	10.5
Prefer full instructions	84.8	13.0	2.2	57.8	28.0	14.2
Does not illustrate how theory arises	19.6	28.3	52.2	16.1	22.0	61.9
Essential part of chemistry	100.0	0.0	0.0	93.7	3.5	2.8
Help support lectures	82.6	13.0	4.3	78.5	12.1	9.4

The third reason identified by staff, *developing deduction, interpretation skills*, as seen was less important by students (Table 3). Staff clearly think that practical work should develop deduction and interpretation skills, but perhaps there is not enough emphasis that students should be developing these skills or perhaps are not aware that they are developing these skills.

'Teaching experimental design' was not identified as one of the top three reasons by staff or students (Table 3) and also was not identified as being developed (68% of students agree with the statement 'I don't get the opportunity to design experiments' (Table 4). Students identified that the predominant type of practical work carried out in the first three years is expository (Figure 2a). This involves carrying out experiments in a recipe approach, with no room for a student to diverge from the set method. It is not surprising therefore that students do not identify teaching experimental design as a key reason for including practical work in the course. It is unlikely they will come across experimental design until the third or fourth year in which they begin to undergo a greater amount of inquiry and discovery type of practical work (Figure 2a) in which experimental design will be used to plan their own experiments.

As students progress through their course, they are more likely to get the chance to design experiments within practical work, with 77% of first year's, 77% of second year's, 52% of third year's and 37% of fourth year's agreeing that they do not get the opportunity to design experiments. This would fit with the change in the type of practical work predominately carried out by students in different years (Figure 2a), with first year's predominately carrying out expository which involves simply following a set procedure, and fourth year's carrying out inquiry type of practical work more predominantly which will give students a chance to design their own experiments.

Practical work for developing transferable skills
Practical work can be used to develop transferable skills[4]. However, in this study, neither staff nor students rated developing these skills particularly highly. *'Developing team working skills'*, '*developing time management skills'* appear within the lowest three reasons identified by both staff and students. Students do identify that practical work does develop these skills (Table 4; 63% disagree with the statement *'I do not get the chance to work in a team during practical work'*). The QAA and RSC highlight the importance of the development of transferrable skills, but this reveals staff do not believe this is an important reason for including practical work.

Students believe their time management skills are developed to a greater extent than staff believe they are (73% agreement compared to 61% of staff; Table 4). Staff believe that interpretation skills of students are developed (87% agreement), and fewer student believe this (72%). This could imply that students are not aware of these skills being developed.

There is also agreement that practical work helps develop team working skills, (65% of staff disagree with the statement '*Students do not get the chance to work in a team during practical work'* and 63% of students disagree; Table 4).

'Developing problem solving skills' was chosen as one of the top three reasons by a higher number of both staff (35%) and students (27%) (Table 3). Interestingly, fourth year students rate developing problem solving skills as the third most important reason for including practical work (42%).

Practical work for supporting learning
There is mixed response to the inclusion of practical work being to support learning. Staff rated *'Showing how theory arises from experimentation'* seventh, compared to students rating this as second, and '*Illustrating key concepts'* was given the same rating, fourth most important by both (Table 3). *'Seeing things for 'real''* was also chosen in the top three reasons by a similar number of staff (26%) and students (24%). Both groups see practical work as contributing to some extent to supporting learning gained elsewhere.

More staff think that practical work helps illustrate key concepts, 94% compared to 81% of students, suggesting students are not aware of this and are perhaps not making the link.

Both staff and students did agree that in reality practical work helps support learning. Students agreed that practical work helps them to learn more chemistry (82%) and helps understanding of chemistry (79%), and staff also agreed that practical work helps students to learn more chemistry (87%; Table 4). Staff and students both agree to a similar extent that practical work helps support lectures, 83% of staff agree and 79% of students agree. This suggests staff expect practical work to help support lectures, and students are indeed experiencing this.

More staff think that practical work helps illustrate key concepts, 94% compared to 81% of students (Table 4), suggesting students are not aware of this and are perhaps not making the link. This may be due to issues of course structure, as practical work may not be able to be scheduled to relate to appropriate lectures, leading to practical work being seen as isolated exercises[11]. Staff also have a greater agreement that practical work helps students to understand chemistry, 94% compared to only 79% of students agreeing with this. This suggests that students are not taking away as much from practical work as staff think they are with regards to learning chemistry. This would support the idea there is little evidence to suggest practical work adds to student learning[20].

Practical work for accreditation

The least important reason identified by staff, *to achieve Royal Society of Chemistry accreditation* (Table 3), was not given as an option to students as they are not involved in accreditation. It is clear staff do not think this is a particularly valid reason for including practical work, even though the majority of chemistry courses in England are accredited[1].

Experience of practical work

The majority of student respondents (71%) feel confident carrying out practical work (Table 4) suggesting that they acquire the appropriate skills needed to carry out the experiments and also that they get any support required. This confidence appears to be greater for student respondents in higher years, with 65% of first year, 75% of second year, 72% of third year and 91% of fourth year students agreeing. This would indicate that students improve their practical skills and hence confidence as they progress.

The majority of students indicated they prefer to have full written instructions for practical work (58%) with only a small amount (14%) disagreeing with this (Table 4). Sneddon *et al.,* reported that the first year physics students surveyed preferred to have written instructions[17]. This is supported by the type of practical work students are currently undertaking, dominated by expository in which written instructions will be provided (Figure 2a). However, when asked what practical work students would like to do, they favoured the other types of practical work (Figure 2b) which would not necessary rely on instructions, but give students more freedom to follow their own experiments. This does not support students indicating they prefer written instructions, so perhaps they are more comfortable with what they are used to.

85% of staff believe students prefer to have full instructions, but only 58% of students agree with this. Student respondents in higher years indicate less of a preference for full written instructions. This could be due to students' experience of different types of practical work. By the fourth year the majority of students are undergoing research projects (Figure 2a), which will not have instructions and so they have more experience of not having written instructions and perhaps see a benefit and preference for not receiving full instructions.

Staff believe that students rely on written instructions without fully understanding the procedure to a much greater extent than students claim they do, 76% of staff agree compare to only 43% of students (Table 4). Sneddon *et al* reported similar findings, in which the physics students surveyed stated they did not reply on instructions without understanding the procedure[17]. This suggests either students are engaging with practical work to a greater extent than staff think they are, or that students believe they are engaging with the work and not relying on written instructions. There is evidence in the literature to suggest students do indeed follow instructions without understanding[4]. This seems to be what staff are experiencing and may be a downfall of the type of practical work being followed, for example expository which allows students to simply follow instructions. By the fourth year, students appear to rely less on full written instructions with only 26% indicating they rely on following written instructions without fully understanding the procedure. This would indicate that as students become more confident with their practical skills and have more experience, they are able to engage more with the practical work being carried out, giving progression in skills development[4].

There is strong agreement that staff and students see practical work as being essential to the chemistry course (Table 4). They both clearly see practical work as being useful for developing a wide range of skills as well as supporting learning elsewhere in the chemistry curricula. This may be supported by the fact that the majority of students feel practical work will be useful to their future careers (70%). The majority also indicate that practical work increases their motivation to study chemistry (60%). This motivation is more likely to be identified by students in higher years, with 71% of fourth year students and only 52% of first year students agreeing that practical work increases their motivation to study chemistry. First year students identify expository as the main type of practical work being followed (Figure 2a) whereas fourth year students are more likely to be carrying out a research style project, so perhaps this increases their motivation to study chemistry as it is more aligned with real chemistry experiments[19]. Perhaps as the main activities carried out are expository, which simply verify something already known to the student, motivation is reduced as suggested by Kirschner and Meester[11].

Both staff and students emphasised the use of practical work to develop scientific skills, with less emphasis on its use to support learning of chemistry.

Conclusions

There are a wide ranging number of objectives that may be present in practical work[11,12,13]. These all cover three general areas of developing practical and scientific skills, developing transferable skills and supporting learning. This research found that staff and students have similar ideas about why practical work is included, and feel that students are achieving these aims. It is clear that both staff and students see the benefits of practical work in terms of skills developed. The most common reason given is to develop practical skills. Both staff and students emphasised the use of practical work to develop scientific skills, with less emphasis on its use to support learning of chemistry. Students are more likely to identify the use of practical work to promote learning elsewhere. What is still not clear is if students do actually learn anything from practical work or it simply develops both scientific and transferable skills.

This work has built on previous work to examine the types of practical work currently being carried out in undergraduate chemistry courses in England. Meester and Maskill found that expository types of practical work dominated in chemistry first year practicals[18]. This research shows this is still the case, 15 years on. Expository is seen as limited in its ability to develop students into scientists as it encourage them to simply follow instructions without thinking and encourage passive learning[10]. These are cheap and easy to run with large numbers of students[2]. It is easy to see why universities rely on these methods when the financial climate is increasingly uncertain. It is important that it is clear what the objectives of practical work are and the appropriate method is used to reach these objects. This research found that staff agree that this is a more desirable method for first year students, perhaps as it allows them to gain experience in basic techniques without getting confused by other details[5].

Inquiry based activities seem to be well established in the final years of practical work, which commonly involve an extensive open ended investigation[1] and this research has confirmed this. There is little evidence to suggest this type is used in lower years of a course. Staff appear to believe this type should be introduced earlier in the course, perhaps to allow student to develop skills progressively[2].

Problem based activities do seem to be growing in popularity, with an increasing number of examples being found in the literature[5,10,19]. This type has been shown to have educational benefits such as motivating students and problem solving, as well as helping student understand concepts[6]. It also builds on students prior knowledge so helps them to make connections to other learning.

It would appear that different styles of practical work will suit learners at different stages of development. Each type has advantages and disadvantages and can be used to achieve different outcomes. There is some debate about the true objectives of practical work, but staff and students do appreciate its importance in the curriculum. Whatever the objectives are deemed to be, they must be made clear to the student to ensure they can achieve them, and a suitable pedagogic method must be employed.

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Public engagement with science: ways of thinking and practicing

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Abstract

The primary focus of the Higher Education Institution (HEI) is the generation and dissemination of knowledge. This knowledge is generated and shared throughout the research community and to students specifically enrolled in university programmes. Public engagement with science enables and ensures the generation and sharing of knowledge throughout a wider community.

Public engagement with science has enjoyed an increasingly heightened profile in recent years with six 'Beacons for Public Engagement'[1] being established across HEIs in the UK, including a National Co-ordinating Centre for Public Engagement[2] hosted between the University of Bristol and the University of the West of England In addition, public engagement is a component in the 'Pathways to Impact' statements[3] which have been introduced into all RCUK research funding applications.

However public engagement, and in particular public engagement with science, can often be perceived as an add-on or 'Cinderella' activity to be undertaken only by the dedicated and often only in their own time. This paper argues that public engagement with science is a legitimate area of academic practice in HEIs which complements and extends research and teaching. The paper outlines key principles which underpin public engagement with science and describes effective work practice.

Public engagement enables the sharing of knowledge with a wider, non-specialist community, regardless of the level of previous knowledge of the community...

Introduction

Higher Education institutions are establishments in which knowledge is generated and disseminated. Yet that knowledge often remains 'hidden' within the confines of the academic community. This creates the phenomenon of the 'ivory tower' in which the knowledge generated by a university remains within the academic community and can even remain within individual disciplines. It could be said that, in some instances, the ivory towers are created from the inside by the academic community themselves.

Public engagement enables the sharing of knowledge with a wider, non-specialist community, regardless of the level of previous knowledge of the community and, as a practice, can enable the enrichment and understanding of knowledge by viewing it from different perspectives. Public engagement involves extending the reach of and engagement with a discipline both within and beyond the HEI (Figure 1). Therefore public engagement with science is an extension of the knowledge generation and dissemination of an HEI and lies on a continuum (in the dissemination of knowledge of an HEI) rather than being a completely separate entity.

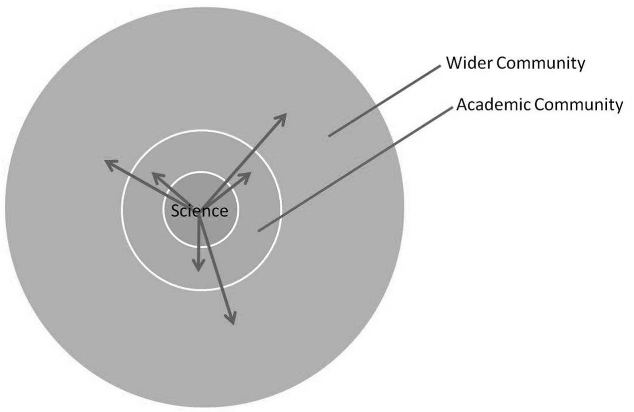

Figure 1: Dissemination of science within and beyond the academic community

The UK Higher Education Funding Councils, Research Funding Councils UK, and the Wellcome Trust have recognised the importance and value of embedding public engagement as a practice in higher education and have established the Beacons for Public Engagement initiative: a four-year project designed to create a culture change across the higher education sector. The Beacons initiative supports six Beacons for Public Engagement across the UK, together with a National Co-ordinating Centre for Public Engagement (NCCPE).[2]

The Beacons project is unique as a culture change project in several aspects:

- The focus of the project is to establish a culture of public engagement across **all** disciplines in HEIs in the UK. HEIs who are not directly involved with any of the six Beacons have access to the knowledge and tools for culture change being generated by the NCCPE[4].
- The project involves the HEI community at all levels e.g. researchers, public engagement practitioners, Heads of Schools, Vice Principals.
- The project is engaging the HEI community in a process of participatory research[5] in order to generate and refine learning about public engagement, to define public engagement and thereby to embed the practice as a legitimate area of work in HEIs.
- Having defined the key purposes for public engagement i.e. informing, consulting and collaborating[6], the Beacons project has employed these ' ways of working' i.e. (informing, consulting and collaborating) in their journey to establish a culture of public engagement in HEIs. The Beacons are "practicing what they preach" says Heather Rea, Project Manager of Edinburgh Beltane, Beacon for Public Engagement.
- Each of the six Beacons, established across the UK, has a different focus. This allows for experimentation in working towards culture change and recognises that different approaches to culture change depend on existing cultures in HEIs and the communities and publics with which they engage.

The focus of the Beacons project is to establish a culture of public engagement practice across **all** disciplines within an HEI. The three main purposes for public engagement as defined by NCCPE are informing, consulting and collaborating. However much of the public engagement with the physical sciences, which is practiced by HEIs, is for the purpose of informing or sharing knowledge: knowledge about key concepts, research findings, potential applications of research or about the research process and the scientific method. Knowledge which is generated by this process of public engagement with science may not be scientific knowledge. It is more likely to be insights regarding the application of the science, insights regarding methodologies for dissemination and insights about misunderstandings of scientific concepts.

Public engagement with science as a 'way of thinking'.
How can one communicate a piece of research or indeed a fundamental scientific concept to a non-specialist audience when it has taken the researcher or scholar many years of study and research to develop the research, and to arrive at the understanding themselves? A different approach is required in order to convey the knowledge, one which does not depend on the audience having been immersed in the discipline and therefore having benefited from the iterative effect of years of gaining knowledge in the discipline. This 'way of thinking' involves viewing the science in the wider context i.e. from a 'bigger picture' perspective. The public engagement with science approach is to view the science from the outside in, rather than from the inside out, taking a step back (or several steps back from the detail) and finding a point or points of common interest with the 'audience'.

Figure 2 shows:

a. shows a photograph of the centre of a sunflower. This is analogous to the level of detail in a research paper.
b. shows the view of a whole sunflower, and illustrates the process of stepping back from the detail of the research paper to view the science in context to enable finding the points of common interest with the audience.
c. shows a whole field of sunflowers, steps back even further to a much wider context.

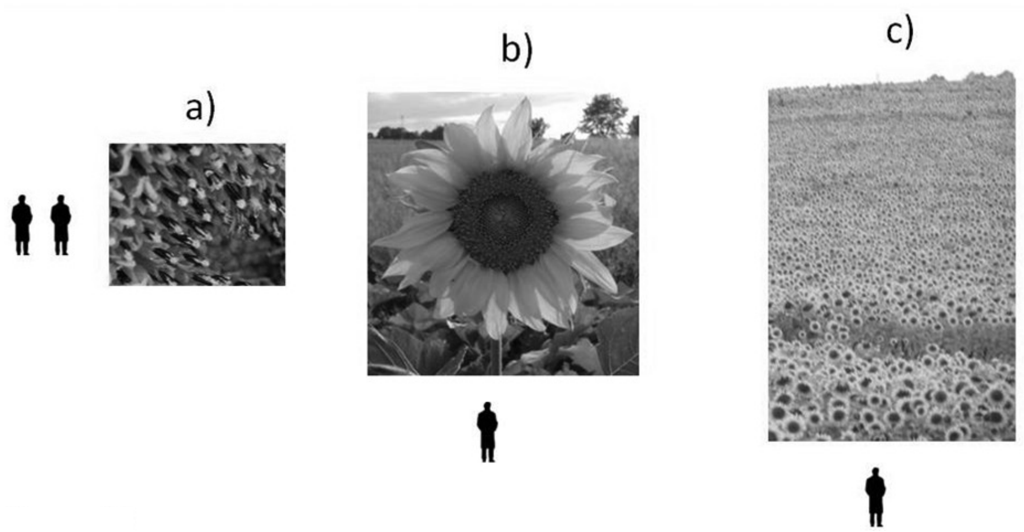

Figure 2: Viewing the science from a wider perspective

In public engagement with science, it is important to choose an appropriate level and 'hook' for both the audience and the purpose of the engagement.

For example, my chemistry research was in Pyrolitic Syntheses of Fused Bridgehead Nitrogen Heterocycles[7]. This description is at an appropriate level for a PhD thesis and for research papers.

Taking a step back, I describe the work as follows: selecting a starting material (i.e. chemical compound) and heating it under vacuum to temperatures of up to 1000 °C. This enables rearrangement (by bonds breaking and reforming in a different configuration) of the original starting material to a different compound. Taking a further step back I use an analogy i.e. the Molecular Anagram. Taking a carefully chosen word (molecule) rearranging the letters (atoms) to form a different word (molecule). The analogy can be extended: sometimes the rearrangement leads to another word (molecule) sometimes leads to nonsense (or in the case of my research, tar!).

Another example is drawn from the staff profiles on the University of Edinburgh, School of Chemistry web-page describing the work of Philip Camp[8].

> *"We study the properties of complex fluids e.g. colloidal suspensions, ferrofluids. Using computational and theoretical techniques, we determine the connections between the structure, dynamics, and phase behaviour of complex fluids, and the properties of the constituent molecules. Then we construct simple molecular models that capture the essential characteristics of real systems and study these models using computational techniques." The above description does not contain the level of detail of a research paper, however it does capture the essence of the work accurately and for a scientific audience. Taking a further step back and for a non-scientist audience, Philip Camp said the following about his and others' work: "Researchers in the School of Chemistry use computer movies to give them amazing insights on the atomic world."*

Taking several steps back from the level of details of the research paper enabled the researchers to describe the key focus of the research in a single sentence. This 'way of thinking' is invaluable within the research community. As multidisciplinary projects become the norm, it is essential that researchers from one discipline can communicate effectively with another to deliver research projects and to explore exciting new avenues of research. This requires stepping back from the level of detail of the research paper in a discipline and exploring the research area or phenomenon at the appropriate level at which communication is productive and conducive to developing a research area.

This 'way of thinking' is necessary when considering 'Impact' of research: in the composition of 'Pathways to Impact' statements now required in funding applications for RCUK and for the Impact Case Studies which will be required for the Research Excellence Framework[9]. The questions to be answered are as follows: Where does the research sit within a wider context, who will benefit and how will they benefit? Impact can be thought of as a tool to assist in the strategic planning of research.

Key principles of public engagement with science.
This 'wider context' approach, when combined with imagination, creativity and lateral thinking are essential in the development of an activity for public engagement. There is a huge range of methodologies and formats employed in public engagement: from the demonstration lecture, interactive exhibits and hands-on workshops through to novel examples such as chemistry comics[10] and maths walks[11].

However, underpinning effective public engagement with science are key guiding principles and practice which are common to all methodologies and formats:

- The science should be accurately represented (the level at which the concept is communicated will not be that of a research paper however the level, analogies used, and methodologies should convey the science accurately).
- The activity should be considered and designed from the audience perspective (i.e. what may be fascinating to a scientist may not be the 'hook' for the non-specialist audience).
- There should be clarity of purpose for the engagement e.g. are you seeking to generate interest, inform, provide a practical experience, clarify understanding, seek information or views
- The experience should be neutral: public engagement is not PR.

"As we understand 'engagement' to require active involvement and mutual benefit it is possible to also draw a line and to exclude certain types of interactions with the public: for instance, PR campaigns, which seek to persuade the public of a particular point of view" [12].

- The engagement experience should aim to produce an enriching experience for the participants. The participants include both the engager and the 'engagee'. This enrichment may be knowledge gained, deeper insight, a different way of looking at or doing something. This is beautifully summed up in a statement by Monty Don[13]. He was referring specifically to gardens, which could be construed as a form of public engagement, however his statement is relevant to all successful public engagement: *"It enlarges us". We should come out (of the experience) "with a whole new set of parameters with which to measure life".*

How does one work towards achieving this effect when planning a public engagement experience? Figure 3[14] presents an invaluable tool for designing and evaluating a public engagement activity:

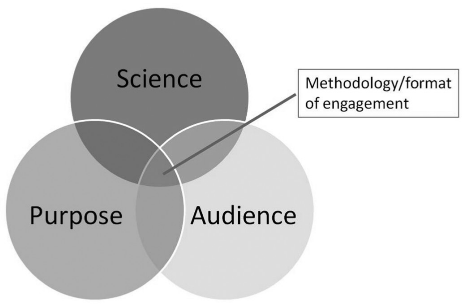

Figure 3: Summary of public engagement with science in practice.

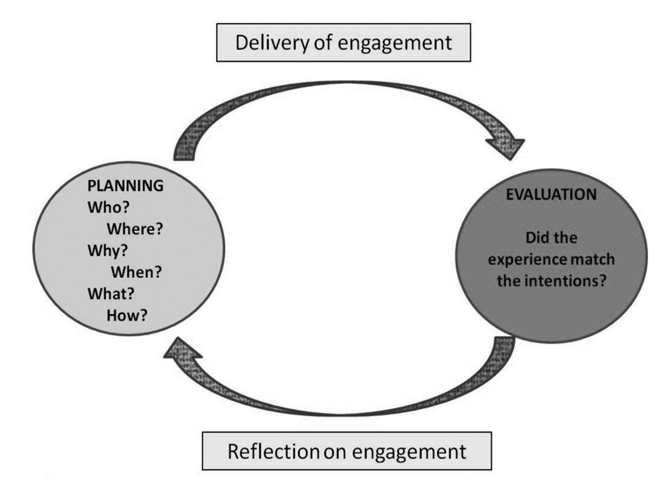

Figure 4: Reflective practice in public engagement with science

Note that the science, audience and purpose of the engagement require equal consideration and ideally the methodology for the public engagement should fall within the overlap of these sectors. By considering the audience and the purpose of the engagement from the outset, the practitioner can establish realistic objectives and outcomes for the activity or project and build in an effective evaluation strategy at the planning stage.

'Ways of practicing' in public engagement with science.
In addition to the key principles, there are 'ways of practicing' in public engagement with science which are common to all effective science engagement activities:

- Reflective practice
- Professionalism
- Flexibility
- Quid pro quo

Public engagement is very much a 'practice based' area of work in which learning for the practitioner is acquired through practice, rather than through theory. However, reflective practice is essential for effective development as a practitioner in public engagement as indeed it is for other areas of work including teaching.

By asking the questions (who, where, why, when, what and how) during the design and development of an engagement activity enables the practitioner to identify and access the knowledge, experience and support required for the activity. By having a clear idea of the purpose of the activity the practitioner can then evaluate the effectiveness of the activity by comparing the experience with the intention. The insights gained from this process inform subsequent engagement[15]. Reflection in practice[16] is also vitally important in public engagement, particularly when there is direct interaction between the engager and the audience. A personal maxim of mine is that in any face-to-face public engagement activity: 'Something unexpected will occur! You won't know what it is until it happens but you can be sure it will happen'. Reflection in practice, professionalism and flexibility are critical in these circumstances. Being able to adapt the engagement experience in real time requires good awareness, problem-solving ability, imagination, creativity and experience.

Rarely do you have the luxury of the perfect venue, a homogenous audience or perfectly aligned expectations, so an ability to reflect and act in practice, to behave professionally and to be flexible and creative in resolving issues is essential. These are key transferable skills, some of which are identified in the Chemistry Benchmarking Document[17].

Let's not forget that the unexpected can be a challenge to address or it can be a completely unplanned outcome which enriches and expands the activity. Having the ability to 'reflect in practice' enables the practitioner to recognise and develop these unplanned, but nevertheless, enriching experiences. Professionalism also manifests itself in very practical considerations: e.g. Risk Assessment Procedures, Criminal Records Bureau/Disclosure[18] checks (particularly when working with children), awareness of Employers' Liability Insurance, Copyright Law. A practitioner should demonstrate resourcefulness and appropriate initiative. In any engagement experience the engager is an ambassador for the discipline, the HEI and for the scientific community as a whole.

Finally, public engagement in practice often depends on mutually beneficial arrangements between organisations or between practitioners themselves. A culture of collaboration and interdependence exists between public engagement practitioners which is synergic for design and delivery of activities. This can be at a very simple level for example at the recent Edinburgh International Science Festival, we borrowed a lamp from colleagues and in return we loaned a UV light box. At a different level, I was invited to participate in a project for which a colleague required complementary activities. This presented an opportunity for me to work with a different audience and in turn my colleague was able to fulfil the obligations of her project. These are both fairly pragmatic examples of the 'quid pro quo' culture which exists in public engagement. At a different and more creative level, many public engagement activities and projects are enriched or depend on collaborations between scientists and other institutions and/or areas of expertise: for example museums, galleries, theatres, artists, musicians. The most effective collaborations exist where there is a symbiotic and synergic partnership which extends beyond the life of the project and results in the generation of new and even more innovative engagement[19].

Principles in Practice
The principles and ways of practicing have been distilled, by the author of the paper, from over 10+ years practice in public engagement. To demonstrate these key principles and ways of practicing, two examples of work have been chosen: 1) an in-depth description of how a well-known chemistry demonstration is delivered in schools, and 2) an overview of a grant funded project. These examples demonstrate that the key principles and ways of practicing are relevant to public engagement with science regardless of the scale of the activity.

Example 1
Adapted from 'Demonstrating the colour changes of indicators using dry-ice'[20].
This was one of the first chemistry demonstrations I learned and it forms the core of many of my demonstration lectures. The demonstration would be one component of a chemistry demonstration lecture delivered in a school classroom for age group 11-14 year olds. Dry-ice is not usually available in

schools and is a novel means by which to make an acidic solution. A questioning style is used throughout the presentation allowing many opportunities for audience interaction and participation and is an invaluable skill when applied in undergraduate teaching. When visiting a school, the audience consists of both pupils and teacher(s). The aims of the visit are the following:

- To complement the work being carried out in the classroom or to introduce future topics (Feedback from teachers indicates that it is useful if a 'visitor' to the school can reinforce or introduce concepts taught in the classroom e.g. the pH scale
- To enthuse and pupils about chemistry
- To show the relevance of chemistry in everyday life
- To provide opportunities for knowledge gained during the demonstration to be to be applied to further examples and questions.
- To demonstrate that science is not a collection of unrelated facts.
- For me as a practitioner, to expand my experience and knowledge of working with a particular audience and to gain insights about misconceptions in science and the practice of science.

This particular experiment involves adding a few drops of Universal Indicator (a pHindicator with colour changes across pH range 1-14) to a volume of water. It is helpful to display the colours of the indicators on a chart. We expect the water to be around pH 7. The colour of the indicator for pH 7 is green, therefore (in most cases!) the water becomes green on addition of the indicator. Then a few drops of vinegar are added to the indicator solution. References can be made to other household and everyday substances which are acids such lemon juice and battery acid. The solution turns from green to red *on the addition of a colourless liquid (vinegar).* Let's not forget that this is really amazing for someone who has not seen this before. The colour of the solution corresponds to ~pH 2 on the indicator range confirming that vinegar is an acidic solution. Then a few drops of sodium hydroxide are added (to the same flask). References can be made to Mr Muscle drain cleaner (in which sodium hydroxide is a major component), and other common household alkaline solutions such as shampoo and soap. We are adding a colourless solution to a red solution and the solution turns purple, which corresponds to around pH 14. Now that we know the colours of the indicator for acid, alkali and neutral, we can test whether Dry-ice (solid carbon dioxide) forms an acidic or alkaline solution. Adding the Dry-ice to the purple solution produces a wonderful effect with plumes of fumes (moisture from the atmosphere condensing on the carbon dioxide gas which has sublimed from the solid carbon dioxide) plus we can observe the colour changes across the full range of the Universal Indicator as carbon dioxide in water is an acidic solution and so the colour reverts back to red. The audience can then deduce that carbon dioxide in water is an acidic solution which is why fizzy drinks (which contain carbon dioxide) are not so good for the teeth. The level of explanation of the science can be varied depending on the audience e.g. acids and alkalis, pH scale, $pH = -\log_{10} [H_3O^+]$. Making reference to household substances ensures points of contact with the audience and demonstrates that chemistry and chemicals are not confined to the laboratory. I make the point that everything which is solid, liquid or gas is a chemical, some chemicals are more harmful than others. I also inform the audience that there is a lot of chemistry going in the room in which they are in, and do they know where this chemistry is taking place. It's very gratifying when eleven year old pupils respond by asking variations of: "Is there chemistry going on in our cells?" I extend the demonstration by asking the audience to apply their new knowledge about Universal Indicator and pH by asking the question: If I was wearing a jumper dyed with Universal Indicator, what colour would it go if I a) stepped out into acid rain? b) washed the jumper with soap powder? The demonstration was extended to include the pH component of the Global Water Experiment for International Year of Chemistry 2011[21]. This involved using two further indicators (bromothymol blue and *m*-cresol purple) to test water samples collected by the school. The experiment was framed in the wider context of availability of clean drinking water in the UK, contrasting this with availability of clean drinking water in other parts of the world and highlighting the tests and procedures required to ensure that water is safe for drinking. The pupils also learned that, regardless of the indicator used in an experiment, the pH scale is used universally to measure the acidity of a substance. The 'performance' of the demonstration can be amended, adapted and extended to meet audience requirements.

Demonstrating key principles:
The science is accurate at a level appropriate for the audience. References are made to household substances which are familiar to the audience in order to establish common points of interest and knowledge before introducing new concepts. By providing references to everyday substances, this enables pupils to recognise that chemistry and chemicals are part of their everyday life and not something which is only experienced in the laboratory during chemistry lessons. Care is taken to give balanced information: for example explaining that chemicals can be essential, beneficial or harmful to humans and to the environment; and this applies to man-made as well as naturally occurring chemicals. By enabling the pupils to apply the knowledge gained during the demonstration to other example (the Universal Indicator jumper), this illustrates the application of a fundamental concept in a different context and allows the pupils to test their understanding of the concept and extend their understanding.

Therefore the key principles of accuracy of science, point of common interest, clarity of purpose (defined in the aims) neutrality, and a net gain or insight are satisfied. As a bonus I acquired a new name during one school visit: 'the Ice-Lady'!

Demonstrating 'Ways of Practicing':
The aims are clearly defined and provide guidance in the design and delivery of the activity. By reflecting on the audience reactions, perceptions and understanding during and after the visit, the demonstration can be refined and adapted as necessary. The 'Dry-ice demonstration is one component of a demonstration lecture which has to be flexible enough to expand or contract depending on the class time available which can vary between school by as much as 30 minutes. It is unrealistic to expect schools to reschedule class times to suit one visitor. Risk Assessments are of course carried out and provided to the school. The demonstration has evolved and has been adapted for different contexts including a hands-on version as a component of a workshop. It was possible to include the pH component of the IYC Global Water Experiment to give a wider context to the introduction of pH

and I requested that the school collect water samples. Whilst we do not charge for workshops and demonstrations, we do insist that schools participate in the evaluation of the activity during the visit and by providing comments after the event. Reflective practice, professionalism, flexibility and quid pro quo are all demonstrated in this example.

Example 2
The second example is based on the project 'Superbugs' - a Challenge for 21st Century Scientists[22] which was a Wellcome Trust funded People Award. This was a collaborative project between researchers and public engagement practitioners. The researchers were exploring the pathology of a superbug (*Burkholderia cenocepacia*) which affects individuals with Cystic Fibrosis (CF).

The aim of the project was to raise awareness of superbugs and of the multidisciplinary approaches required to combat them. This was achieved by delivering combined hands-on/ discussion workshops for school pupils together with public events at the Edinburgh International Science Festival, in the National Museums Scotland and at the Edinburgh Festival Fringe. The workshops consisted of hands-on activities exploring the following: effective hand-washing, structure and functionality of bacteria, identification, diagnosis and treatment of superbug infections. The discussion activities explored the implications of superbugs in everyday life and in the lives of individuals who have CF.

During the project the following took place: over 20 schools participated in workshops; 5 days of activities were delivered at the Edinburgh International Science Festival (average of 800 visitors per day ~200 of whom spent 20 minutes or more at the activity); 3 days of activities at the National Museums Scotland (around 100 visitors, per day who spent 20 minutes or more at the activities); 2 days of activities at the Edinburgh Festival Fringe (around 70 visitors per day. The audiences for the public events were often children accompanied by relatives/carers (often grandparents). The workshop resources have subsequently been modified so that they can be delivered by teachers in schools. CDs of resources including video footage of bad hand hygiene practice were distributed to all schools who participated in activities and to other schools visited by University of Edinburgh as part of their outreach programme.

The key learning outcomes designed for the project were as follows:

- importance of hand-hygiene
- causes of antibiotic resistance of bacteria
- an understanding of the multidisciplinary approach required to address the issue of superbugs

These were successfully communicated and discussed with participants (indicated by the project evaluation data). The hands-on workshops were well received in schools (with pupils and teachers) and complemented key learning outcomes in science, health and well-being and social studies in the Curriculum for Excellence[23] (launched in Scottish schools in 2010). The project provided valuable experience and development in public engagement practice for post-graduate students from the School of Chemistry and Biological Sciences and for the researchers involved in the project.

Demonstrating key principles:
The issue of superbugs and hospital hygiene is constantly in the news and provides a very topical and practical focus for both hands-on and discussion activities. The 'Superbugs' project built on the success of the 'Biomedical Horizons'[24] project (Wellcome People Award 2005). One of the hands-on activities which was very popular in Biomedical Horizons was the use of a light box which illuminates areas of the hand which have not been washed thoroughly. In 'Biomedical Horizons' we found that by actively involving participants in hands-on activities early on in the workshop had the effect of generating a more relaxed and inclusive discussion about the science and about issues raised by the workshop. The hand-washing component of 'Superbugs' was a simple yet effective activity to engage participants immediately and which provoked discussion about the transfer of bacteria.

Another activity involved building a superbug from its component parts e.g. cell membrane, cell wall, ribosomes, plasmids, flagella. This enabled a discussion about how researchers might approach the development of potential antibiotic therapies i.e. by studying the formation and function of components of the cells of superbugs, researchers are able to identify potential weaknesses which could be exploited for the development of therapies. For example in the case of the superbug *Burkholderia cenocepacia* the weakness appeared to be the chemistry of the outer cell wall synthesis[25]. Thus we were able to communicate the research work accurately but at a level appropriate for the audience and demonstrate that chemists and microbiologists were involved in the research.

A second activity involved the pupils following evidence to diagnose and prescribe treatment for the infections of fictional patients. This was originally designed for more senior pupils (16-18 year olds) and adults but proved so popular that a simpler version was designed for younger participants. The pupils commented that they enjoyed following through the procedure of diagnosis and treatment, using information they had learned, and applying it in a fictional case. The workshops highlighted the fact that it was not only medical doctors who were involved in this work but chemists and microbiologists ranging from eminent researchers to laboratory technicians. The PhD student helpers valued the experience in communicating and discussing areas of science with school level pupils and discovering pupil perceptions of scientists.

Demonstrating 'Ways of Practicing':
The objectives for the project together with the public engagement methodologies are defined in funding proposal s which ensures that much of the strategic planning is completed before the funding is awarded and enables the design of an effective evaluation strategy for the project at the outset.

The activities were trialled then amended after feedback from a teacher with whom we worked in partnership. The activities were designed to be flexible and able to be adapted and updated depending on the circumstances and audiences to which they were being delivered. PhD students helpers and laboratory technicians from the CF project were given both generic and workshop specific science communication and were encouraged to, and indeed did, reflect on their delivery of workshops as evidenced by their feedback in evaluation. By working closely with researchers, aspects of their research were accurately disseminated to an audience beyond the academic community.

Conclusions

Public engagement with science is a practice which enables, extends and enriches the generation and particularly the dissemination of knowledge to various publics within and beyond academia.

Public engagement is a 'way of thinking' about science i.e. thinking about the science from the overview, from the wider context, and then identifying common points of interest/ knowledge/experience with an audience. The key principles for public engagement with science are the following:

- Accuracy of science
- The 'audience perspective' as the starting point
- Clarity of purpose
- Neutrality
- Enriching experience i.e. there should be a 'net gain' for all participants as a result of the public engagement.

Public engagement with science is developing its own 'Community of Practice' with reflective practice, professionalism, flexibility and quid pro quo being the cornerstones of effective practice.

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Ausubel's principle of prior knowledge in first year mechanics

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In Physics education research has revealed that students can demonstrate alternative conceptions of the physical world that are not only stubbornly resistant to change but can actively inhibit the learning of Newtonian ideas.

Abstract

The Force Concept Inventory, a 30-question multiple choice test, has been used to test the baseline knowledge in mechanics prior to a course of instruction at Hull over the three years corresponding to entry in 2008, 2009 and 2010. Students whose pre-university education occurred outside the UK or who were repeating the year have been excluded from the analysis in order to focus attention on first-time UK students. These constitute the great majority of the entrants and the results essentially characterise the entry-level knowledge of a typical cohort. Two interesting findings have emerged. First, there is a wide range of abilities within each cohort, as judged by the test scores, and secondly, analysis of the scores question by question reveals a remarkable consistency between the different cohorts. This consistency extends even to the distribution of choices within individual questions. Five such questions are analysed in detailed to reveal which aspects of mechanics a typical class finds difficult. Ausubel's principle of first finding out what students know in order to teach accordingly can therefore be applied not to the individual students but to the class as a whole and suggestions as to how instruction might be tailored to address the weaknesses revealed by the Force Concept Inventory are discussed.

Introduction

It was David Ausubel who famously wrote[1], *"The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly".* Nowhere is this more true than in mechanics. Physics education research has revealed that students can demonstrate alternative conceptions of the physical world that are not only stubbornly resistant to change but can actively inhibit the learning of Newtonian ideas. For example, Andrea di Sessa[2] reports in a study from the 1980s that both graduate students and young children exhibit very similar naïve views, implying that these alternative views develop early in childhood and can persist right through the subsequent years of formal education, even beyond graduation. It's not enough simply to determine that students don't know, say, Newton's third law of motion, we also need to know what view they hold in its stead. Fortunately, this is relatively easy in mechanics as the force concept inventory (FCI) provides a well known test of understanding in mechanics[3]. Indeed, the FCI has played some part in revealing how common are some of these alternative conceptions.

For readers not familiar with the FCI, and who might in consequence regard it as simply a questionnaire about mechanics, some background about its development is necessary. The questionnaire was developed over many years following interviews with students about their views of mechanics and is designed to test not only whether students are familiar with, and can use, Newtonian concepts, but also what concepts might be held instead. The possible answers to the questions incorporate the naïve views of mechanics concepts revealed by the interviews, such as the so-called "impetus principle" that force must exist in the direction of motion. The idea behind this is to avoid the principal weakness of multiple choice questionnaires, namely that respondents might simply guess the answers. The premise upon which the FCI is based is that students either know the answer or believe they know the answer and therefore have no need to guess. A few questions also require qualitative reasoning in order to arrive at the answer and the question then tests the application of Newtonian concepts. Following the development of the FCI concept inventories are now finding application in a range of disciplines outside physics[4], but the FCI is still the most widely used.

The validity of the FCI as an instrument for measuring conceptual understanding is much discussed within the open literature[4,5,6]. In particular, the question has arisen[7,8,9] as to whether the FCI provides a measure of a student's coherent understanding of the force concept or whether it provides a snapshot of different aspects of their knowledge and understanding. This question is side-stepped here by focussing explicitly on the responses to specific questions. For the past three years the first year cohort at Hull has been tested using the FCI prior to a course of instruction in mechanics based around modelling in VPython[10]. The pattern of responses is examined question by question to show how the FCI reveals the collective knowledge, misunderstandings and deficiencies among typical entrants to a UK physics degree. Five questions in particular are selected to illustrate problems with understanding Newton's third law of motion and the existence of alternative conceptions such as the impetus principle.

Methodology

The FCI was given to the majority of the class prior to instruction in mechanics in order to establish their baseline knowledge. The intention was to test all students in order to determine the baseline knowledge of the class prior to instruction, but those who were repeating the year or whose pre-university education occurred outside the UK were excluded from this analysis in order to concentrate primarily on the knowledge of typical UK university entrants. Ideally the whole class would have been tested, but some students were absent and were not subsequently tested. Nonetheless, a large majority of the eligible students from each cohort was tested; 84.8% in 2008, 96.0% in 2009 and 75.4% in 2010. The mechanics course was run in semester two for each of the years represented in this survey and in 2008 and 2009 the test was administered during the first class. In 2010 the test was administered during the induction week following registration, and this difference appears to be responsible for the reduction in the number of students tested. The tests were all untimed, with students being left to complete the test in their own time.

Results

Figure 1 shows the range of scores from the FCI corresponding to the intakes in 2008, 2009 and 2010. In all years the most common score is typically around 15, but there are scores as low as 2 in 2008 and as high as 29 in 2010. The mean score in 2010 is slightly higher than in both 2008 and 2009 and reasons for this are being sought within average A-level scores in this intake. Nonetheless, the range of results across all years is very similar and makes it difficult to decide what to teach and at what level. In all years there are clearly students who have a good understanding of mechanics principles whilst there are also a significant number of students who do not.

Despite this wide variation in scores across the class, the breakdown of responses question by question (figure 2) reveals that the classes behave in a very similar manner. Although there are differences, especially between the 2008 and 2010 cohorts with a slightly higher proportion of the latter cohort giving the correct answers, there are also striking similarities. Where the majority of students give the correct answer in one year the same happens in the other years. Likewise, where the majority of students appear to struggle the same is also true in other years.

Three questions stand out as producing anomalously low numbers of correct responses; 5, 15 and 26. In fact, as judged by the 2009 and 2010 cohorts question 5 appears quite similar to question 13, but the very low number of correct responses in 2008 marks this question out. We therefore concentrate on these three questions in addition to questions 2 and 11. These last two are answered correctly by about 40% of the class, and as such do not stand out especially, but we focus on them for different reasons. Question 2 is interesting because it relates directly to question 1, which around 80% of the class answer correctly. Question 11 indicates a particular alternative conception held by a significant proportion of the class. Detailed analysis of these five questions, 2,5,11, 15 and 26, shows that not only do the different cohorts behave similarly when choosing the correct response, but also when choosing the incorrect responses.

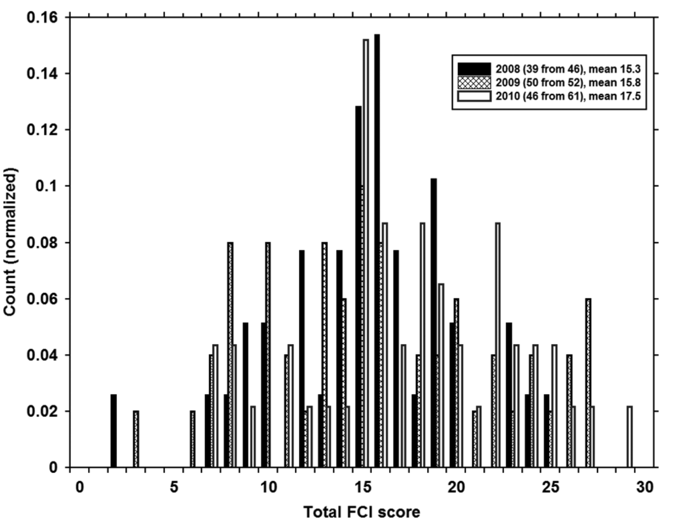

Figure 1. The incidence of total FCI scores across the three cohorts from 2008, 2009 and 2010

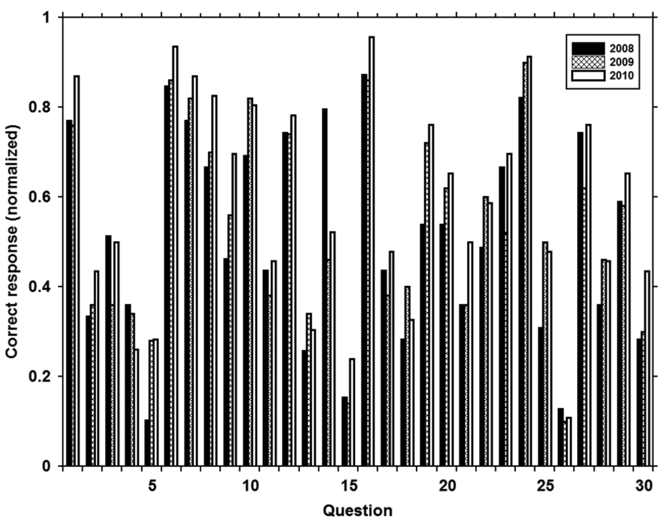

Figure 2: The breakdown of correct responses for each question. Though differences are apparent the trends are remarkably similar

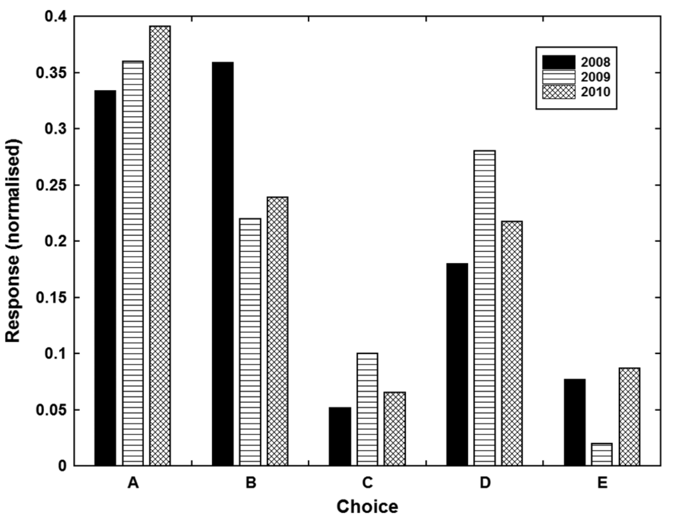

Figure 3: The breakdown of the different responses for question 2

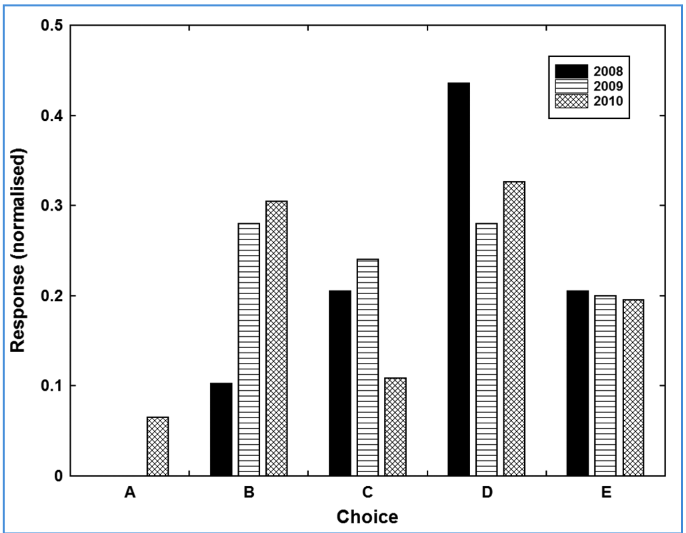

Figure 4: The breakdown of the different responses for question 5

Figure 3 shows the breakdown of the choices for question 2, which can only be understood properly in relation to question 1, which is essentially about the famous experiment at the leaning tower of Pisa. Galileo's is reputed to have dropped two objects of different weights and observed the time taken to reach the ground, but in question 1 the objects are metal spheres, one weighing twice as much as the other, dropped from the roof of a single story building. Students are asked to choose from five possible semi-quantitative answers; for example, does the light ball take twice as long as the heavy ball to reach the ground, half as long, the same amount of time, or some other variation? Question 2 takes matters further and asks if the same two objects were to roll off a horizontal table with the same speed as each other, would the heavier ball land twice as close to the table as the lighter ball, twice as far away, the same distance away, or some other variation? Approximately half as many students as answer question 1 correctly also answer this question correctly (A), but interestingly the majority of incorrect answers in all years have the heavier ball landing closer to the table; half as close in B but considerably closer in D. The options in which the lighter ball lands closer to the table (C and E) are chosen only by a small minority in each year.

The FCI doesn't reveal why students chose particular answers, and for question 1 it is not clear whether students are simply aware of the historical association with Galileo and therefore know the answer or whether they have reasoned out that the two balls must hit the ground at the same time because they are subject to the same acceleration. Likewise, it is not clear whether those who have answered question 2 correctly have reasoned out the answer or simply know it. The interesting fact is that there is a very large difference between the numbers answering the two questions correctly and the question arises as to why students are unable to reason out the answer. Two possibilities exist. First, it is evident from question 1 that the great majority of students should recognise that the two balls take exactly the same time to reach the floor, but students' knowledge is known to be context dependent[11] and there is also evidence that students can hold conflicting views simultaneously[12]. It is possible, therefore, that changing the context from a roof top from which the balls are simply dropped to a table top from which the balls are launched with a horizontal velocity could lead students to fail to recognize that the flight times are equal. The second possibility is that the students know that the flight times are equal, as demonstrated in question 1, but that a significant number are unable to apply this knowledge and reason out that, as the horizontal velocity remains unaffected by the acceleration due to gravity, the identical horizontal distances travelled must also be equal.

Figure 4 shows the breakdown of choices for question 5, with again strong similarities among the different years. In this question students are presented with the scenario of a frictionless channel with essentially a semi-circular profile placed on a horizontal table top. A ball enters the channel at a point *p* and exits at a point *r* having moved just over half the circumference of the circle. Students are asked to identify which of four forces are acting on the ball whilst it is at a point *q* in the channel; a downward force of gravity, a force exerted by the channel pointing from *q* towards the centre of the circle, an opposite force pointing from the centre to *q*, and a force in the direction of motion. The last two do not exist and the correct combination comprises the first two forces only (choice B). Choice A identifies only the force of gravity and was not chosen by any students in 2008 and 2009, and only a handful of students in 2010. Choices C, D, and E, which collectively make up some 60-70% of the class, all identify among the combinations a force pointing in the direction of motion. As described, this a well known alternative conception about force.

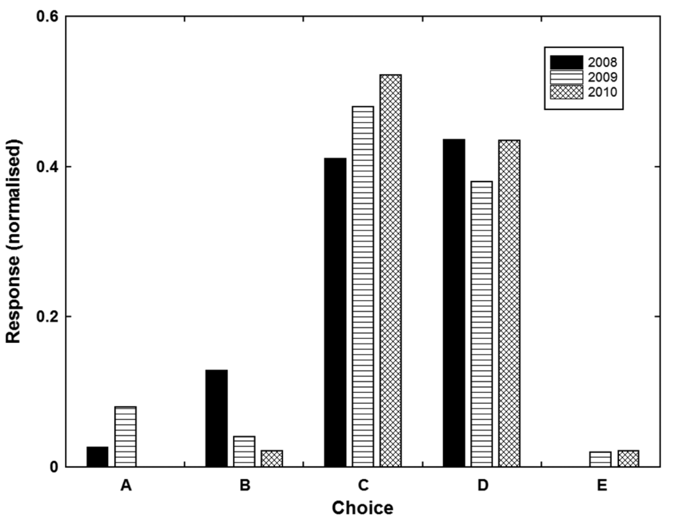

Figure 5: The breakdown of the different responses for question 11

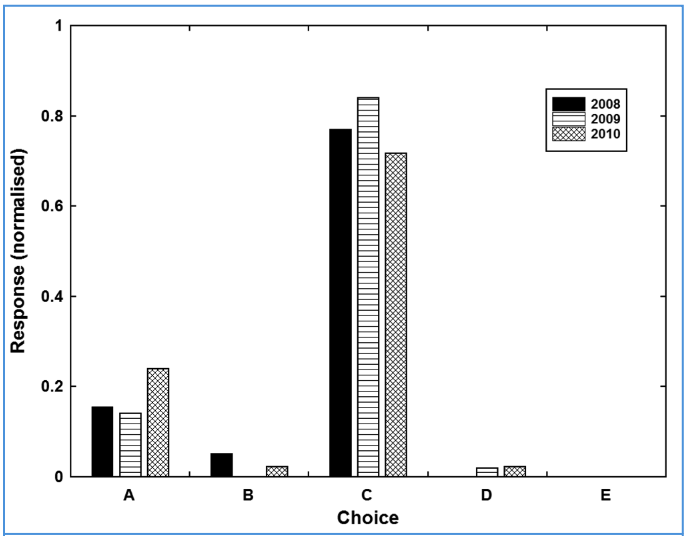

Figure 6: The breakdown of the different responses for question 15

There are differences between the years, but those differences are also revealing. For example, in the 2008 cohort the number choosing B is significantly smaller than in 2009 and 2010, but interestingly those people appear to have chose D instead. B and D are the only two options that identify a force acting from the ball to the centre, so it is consistently the case over the three years tested that only 30% of students can correctly identify this force as acting in this system. Likewise in 2010 there is a group of students who appear to have chosen A over C compared with the other two cohorts. However, these two are the only two options that do not identify any force between the ball and the centre and so again the proportion of the class who do not recognise such a forced is consistent from year to year at around 20%. A similar number in each of the years have chosen E and would therefore appear to believe that a force points from the centre to the ball. The numbers choosing these different incorrect answers might not in themselves be significant, but the consistency from year to year stands out.

Figure 5 shows the breakdown for question 11. As with question 5, students are presented with a body moving horizontally along a frictionless path and are asked to identify the forces acting on it. In this case the body is a hockey puck which has been kicked and is now moving freely. The only forces acting on it therefore comprise the downward force of gravity and an upward reaction. Choices C and D are the only two that identify the upward reaction; choice D correctly identifies only these two, but choice C identifies both of these forces and a force in the direction of motion. Over 80% of the class would appear to recognise the existence of the reaction force, but approximately 55% would appear to believe also in a force in the direction of motion. This is fewer than the number who identify a similar force in question 5, but otherwise supports the existence of this alternative conception among the majority of students. For completeness, other combinations comprise the downward force of gravity only (A), gravity and a force in the direction of motion (B), and no forces at all (E).

Question 15 (figure 6) is related to question 16, which around 90% of students answered correctly. The concept being tested here is Newton's third law of motion and involves a car pushing on a truck. Students are asked to identify in both questions the magnitude of the force the truck exerts on the car in relation to the force the car exerts on the truck. However, in question 15 the car is accelerating whilst in question 16 the car is moving at a constant velocity. In all years the overwhelming choice in question 15 is C, the car exerts a greater force on the truck than the truck exerts on the car, whilst in question 16 the forces are correctly identified as being equal in magnitude. In a number of cases the correct response to 15, A, was crossed out and C selected instead, which indicates that these students at least considered that the forces should be equal but were perhaps confused by the fact that the car is accelerating. Newton's second law identifies acceleration with a nett force and the great majority of students have opted for this. The responses to question 16 should also be considered in this light. On the face of it students would appear to have applied the third law, but the lack of acceleration might have led students to apply, albeit incorrectly, the second law instead and conclude that as the nett force must be zero, so the force exerted by the truck matches that exerted by the car.

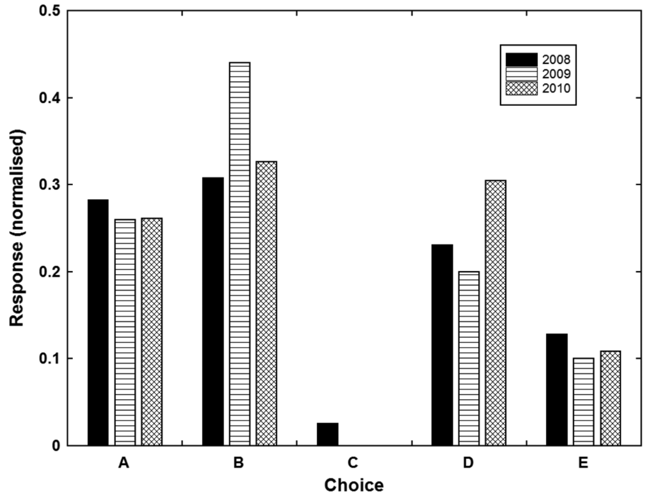

Figure 7: The breakdown of the different responses for question 26

Question 26 relates to Newton's second law, and as with so many questions in the FCI it relates to a situation set up in a previous question. In question 25 students are asked about the magnitude of a force with which a box is pushed across the floor at constant speed. Only 40-50% of students answered correctly that the force is equal in magnitude to the force resisting the motion of the box. Given the apparent confusion between Newton's second and third laws apparent in questions 15 and 16 and that over 80% answered question 16 correctly, this is perhaps a little surprising. In question 26 the force on the box is doubled and students are asked about the motion of the box. Newton's second law requires the box to accelerate (answer E), but as figure 7 shows, answers are split fairly evenly between A, B and D, all of which express some variation on the idea that the speed increases initially but then remains constant. Students are probably guided by their own experience on this question. The question states that the box is pushed by a person and it is easy to imagine pushing a box at different speeds across a floor. Intuitively we might expect that different forces are being applied in each case. It is not really surprising, therefore, that these three options were so popular whilst C and E, both of which involve increasing speeds, were either not chosen or chosen only by a minority. The key to this question lies both in understanding the preceding question and in reading the wording very carefully. Whilst experience might suggest that a box can be pushed across a floor at different speeds, Newton's second law implies that the applied force cannot be constant unless it is equal in magnitude to the resistive force opposing the motion. Indeed, the force applied to the box will vary as first one foot and then the other pushes against the ground and it could be argued that the question is unphysical in the sense that a person cannot generate a constant force over any extended distance. However, the question states that the applied force is doubled and by Newton's second law the box should accelerate.

Conclusion

There is an enormous volume of literature related to the FCI but the author is not aware of a similar analysis of the responses question by question and certainly nothing of this kind in relation to UK students. The present analysis reveals remarkable similarities over the three cohorts, implying that though there might be no such thing as a typical student there is at least a typical cohort characterised by a distribution of correct answers on the FCI. This similarity extends also to the choice of incorrect answers and might well indicate something systematic about the structure of mechanics knowledge at this level. Further analysis is required before such a conclusion can be drawn, but it seems to the author to be quite remarkable that three entirely separate cohorts drawn from different schools around the UK should all demonstrate such a similar structure in their collective knowledge.

Analysis of the FCI scores has also revealed a very large range of capabilities within a cohort, from barely any understanding of mechanics concepts right through to what amounts to a functional understanding. Hestenes has suggested[8] that a total FCI score of 18-20 is the entry threshold to Newtonian thinking; below this score students do not use Newtonian concepts coherently in their thinking. By contrast score of 25 represents the threshold for mastery of Newtonian concepts. Among each cohort there is a group of students who exceeded the first threshold and a small number in both 2009 and 2010 who exceeded the second. According to this criterion the majority of students entering our first year are not Newtonian thinkers and this is reflected in their choice of incorrect answers. These include the idea that a force exists in the direction of motion as well as confusion between the second and third laws and in particular the idea that there can be a nett force acting even when equal and opposite reactive forces within the system are present. In addition, the analysis of question 2 points to an inability to reason qualitatively, either through being unable to recognise pertinent knowledge demonstrated in the previous question or to apply such knowledge.

Having thus identified the prior knowledge characteristic of A-level students entering university, the question then arises as to how to teach accordingly. The ineffectiveness of the traditional lecture in bringing about conceptual change has long been recognised within the physics education research community, largely because students are passive spectators, but within many UK HE institutions the lecture is still the predominant form of instruction[14]. If figure 2 is typical of students entering degree courses in other UK institutions in which the conventional lecture is still favoured there is good reason to suppose that for many such students conceptual development will be slow. Ideally students should be active and Hestenes has long advocated a role for modelling within the curriculum[13]. Modelling in this context means more than setting down mathematical equations and working through to a solution. In Hestenes view this is only one element of a model and in addition to the mathematics students need to be able to identify the different components of both the system and the environment, as well as their properties and interactions. Having developed a model students also need to be able to apply it to other situations in order to consolidate their knowledge. These aspects of modelling need to be taught explicitly, as, according to Hestenes[14], "*Much of it [modelling theory] is so basic and well known to physicists that they take it for granted and fail to realize that it should be taught to students*".

There may be other ways of actively engaging students, but this kind of modelling approach resonates with recent work by Nersessian on the construction of scientific concepts[15] through what she calls “model-based reasoning”. This is the ability to reason qualitatively through the use of various forms of representations and mental models. Although Nersessian was writing about the construction of concepts in the context of research and the development of scientific knowledge, there is no reason why the ideas are not applicable to the construction of concepts in the class room. However, students need to be taught explicitly the value of representing a problem by diagrams, equations, or even just words[16]. The present work has shown that students entering onto a UK physics degree are not in general Newtonian thinkers and that such active methods of instruction might be therefore needed within the UK. A first year mechanics course is as good a place as any to try to start teaching these skills.

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The present work has shown that students entering onto a UK physics degree are not in general Newtonian thinkers and that such active methods of instruction might be therefore needed within the UK.

Solving the maths problem in chemistry: the impact of a pre-university maths summer school

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...we investigate the impact of running a pre-university mathematics summer school for... who have GCSE mathematics as their highest mathematics qualification.

Abstract
Mathematical skills beyond that taught at GCSE level (under 16 in UK) are required to pursue a physical sciences degree in the UK. However, many departments are unable to recruit sufficient students who have both the physical science and Mathematics qualification at A-level (post-16). Therefore, students are admitted with GCSE Mathematics and are taught the mathematical skills during the degree course. In this paper we investigate the impact of running a pre-university mathematics summer school for students about to start a physical sciences degree who have GCSE Mathematics as their highest mathematics qualification. The students are tracked through their first two years of a UK chemistry degree. It is shown that they perform significantly better than similarly qualified students in first year physical chemistry and second year theoretical chemistry units. Reasons for these results are presented.

Introduction
The importance of being equipped with mathematical skills such as calculus, currently not included in a GCSE qualification in mathematics in the UK, for a physical sciences degree is well known[1, 2]. Therefore, there is a strong desire for undergraduates reading degrees in subjects such as chemistry to have successfully studied an A-level (post-16) in mathematics. However, during the 1990s in the UK through to almost the present day, recruiting to a degree in chemistry was hard enough without requiring mathematics A-level. 'The number of students accepted to study for chemistry degrees has mainly decreased since 1994 both in absolute terms and as a proportion of the 18 year old population[3]. While for some institutions it has now become possible to require mathematics A-level for entrance and still maintain entry numbers, for the vast majority this is still impossible and given the introduction of higher fees in 2013 in the U.K. this may never be possible. Therefore, many institutions admit students who have GCSE mathematics (see Shallcross and Walton[2], for a description of the content and an interpretation of what various grades mean) and provide a range of courses to fill in the gaps. In this paper we investigate the effect of running a pre-university mathematics summer school for students about to start a degree in chemistry whose highest qualification in mathematics is a GCSE. Students who took the course were about to start a degree in chemistry at some 12 different universities. However, in this study, only the students who went to study at Bristol (11 out of 30) were tracked through the first two years of their degree and the impact on their results in all areas of chemistry were analysed relative to students with equivalent entry qualifications, who did not attend the summer school.

Details about the summer school
The summer school was run in the second week of September 2008, starting at 2 pm on the Monday and finishing at 1 pm on the Friday. The morning sessions ran from 9.30 am to 1 pm and the afternoon session ran from 2 pm to 5 pm with both sessions having a 30 minute break. All students applying to Bristol to read chemistry who did not have A-level mathematics were invited to attend (around 200 students) the summer school regardless of whether they were eventually coming to Bristol to read for a degree. There were 35 applicants leading to 30 attendees (5 dropped out before the summer school started) and these students came from all over England and Wales. There were no applicants from Scotland or Northern Ireland, although students from these areas were invited. Since the maximum number that could be accommodated was estimated to be 40 there was no need for any selection process or to split the summer school into two. It was known that many of the invitees were not intending to come to Bristol to read for a degree and there was no attempt to select out only Bristol bound students. Of these 30 attendees, 10 were female, 20 were male and of the 11 who were about to come to Bristol, 7 were male and 4 were female. The other 19 summer school attendees were about to start degrees in chemistry at 12 other UK universities. Through funding from the Royal Society of

Chemistry's CFOF project[4] it was possible to cover the cost of accommodation (at a reduced rate, including breakfast) for the week, all lunches, teas and coffees, bench fees and administrative support (~ £175 per student). The students just had to cover the cost of their own evening meals, transport to and from Bristol and had free evenings throughout. There were two types of session; the first was a workshop (4 of these), where a tutor would introduce a topic for no more than 20 minutes and then there would be problems to solve with four tutors (2 academics and 2 postgraduates) available to help students work through them. This would be followed by a short plenary where common mistakes were discussed. Then a new topic would be introduced and the workshop would continue. In all these sessions there was an emphasis on providing a relevant (here chemical) context to the mathematics introduced, something noted by several researchers as being a key to effective cognition of mathematical tools[5-13]. The second session type was a practical one (four of these), either in the teaching laboratories (three) or in a computer laboratory (one). These sessions were designed to allow students to apply basic mathematics used in the laboratory, e.g. yield and purity, moles calculations, logarithms, graph plotting and the exponential function (Beer-Lambert Law) and to collect data to be used in calculus sessions e.g. rates of reaction. It was also felt that 5 days spent in a seminar room working through mathematics problems may not be conducive to learning and so the practical sessions were an important part. When setting up the timetable we decided to have the first 25% of the time as mathematics workshops, the next 50% as practical applications of these tools and the final 25% as an introduction to calculus. The actual timetable was:

Timetable

Monday pm	Basic algebra, orders of magnitude, rearranging equations, applications to chemistry.
Tuesday am	Further algebra, indices, quadratic equations, functions (log, exp, trigonometry).
Tuesday pm	Basic statistics, error analysis with some applications.
Wednesday am	Practicals to emphasise error analysis and basic algebra.
Wednesday pm	Use of Excel in physical chemistry (simulating spectra, functions etc).
Thursday am	Practicals to support the idea of the exponential function (Beer-Lambert Law) and rates of reaction.
Thursday pm	Introduction to calculus (gradients of graphs and functions).
Friday am	Further calculus, differentiation and simple integration.

Worksheets from the course and practical scripts can be obtained from the authors on request. There was a short welcome and introduction to the course on the Monday and a short multiple-choice test using hand-held voting pads, providing instant feedback. This test was repeated at the end of the course.

Results of before and after summer school test

Part of the introduction and plenary of the course was taken up with running an interactive quiz, that was in part to determine what aspects of the course were successful and in part to determine what could be improved from an administrative viewpoint. The questions and their pre and post summer school responses are provided in table 1. In both cases 25 students took part out of the 30 attendees (5 had long journeys and were either arriving later or leaving early).

It is interesting to inspect table 1 and see that in many cases there was a perceived increase in confidence and ability after the summer school, particularly in rearranging equations, using indices and in using standard form. However, equally interesting was the mixed post-response in certain types of mole calculation (concentration and gas volume type) and calculating percentage errors. It emerged during the week, particularly in practical sessions that students thought they knew how to do these type of calculations, but realised that they did not. Most were able to overcome their misconceptions, but some were still struggling at the end of the week. Those that did master these techniques commented that they had not done many practicals where they had to do these type of calculations and that it was good to have had the practical sessions, which helped to reveal the deficiency and also give some context to the problem.

We also asked some mathematics questions at the start of the course, the pre-summer school scores were very low, averaging 24% for algebra and 0% for calculus (there is no calculus in GCSE specifications for mathematics). The same test was given again at the end and the scores rose sharply to 96% for algebra and 76% for calculus. These increases are reassuring but the long-term impact of the summer school was important to assess and are investigated in the next section.

Data collected for Bristol Students

Eleven students from the summer school went on to read for a degree at Bristol. All these students took an in-house run mathematics course in their first year, where they were joined by a further 29 students (who were invited to attend the summer school but declined) who also did not have an A-level in mathematics to make a class total of 40. The results of the first and second year exams in all subjects in chemistry at Bristol for these 40 students (11 attending the summer school and 29 who did not) were collected and analysed, inter-compared and compared also with the rest of the students in the cohort and are shown in table 2.

Table 1: Pre and post summer school responses to the same questions and some post summer school questions

Question	Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
I can rearrange mathematical equations easily	Pre: 3 Post: 12	4 12	14 1	4 0	0 0
I can do moles by mass calculations easily	Pre: 14 Post: 17	11 8	0 0	0 0	0 0
I can do moles by concentration calculations easily	Pre: 12 Post: 17	13 6	0 2	0 0	0 0
I can do moles by gas volume calculations easily	Pre: 5 Post: 6	14 11	4 4	2 4	0 0
I am confident with standard form number representation	Pre: 10 Post: 18	11 6	4 1	0 0	0 0
I am confident calculating percentage errors	Pre: 2 Post: 6	9 8	8 7	6 3	0 1
I am confident converting between units	Pre: 4 Post: 10	15 11	5 4	0 0	0 0
I can plot graphs and error bars	Pre: 5 Post: 8	6 9	6 6	6 2	2 0
I am confident using indices	Pre: 4 Post: 17	13 8	8 0	0 0	0 0
Post only					
Algebra useful Statistics useful Excel useful Practical useful Calculus useful Recommend Summer Sch.	20 7 8 15 21 24	5 11 10 8 4 1	0 4 6 2 0 0	0 3 1 0 0 0	0 0 0 0 0 0

Comments on data in table 2

First, it is striking that the cohort of students who attended the summer school did well across the board in the end of year 1 examinations. They were on a par in inorganic chemistry with the whole year and above average in Physical and Organic Chemistry. In all cases they performed better than those that did not attend the summer school. They also did better than the non summer school students in their own mathematics examination at the end of year 1. This latter result is striking as the percentage of A* and A grades at GCSE mathematics was higher in the non summer school cohort than the cohort that attended. There is no suggestion that the students' organic chemistry or even their inorganic chemistry mark benefitted from attendance at the summer school. Therefore, it is possible that the students who attended the summer school were more motivated and harder working than those that did not and would have gained higher marks anyway. It is interesting to note that on GCSE grade alone the attendees were weaker than the non-attendees and this may have been a contributory factor to their willingness to attend over those that did not.

Table 2: Mean examination results for (a) students without mathematics A level attending the summer school (b) students without maths A level who didn't attend the summer school (c) all students

Year 1	Mathematics	Organic	Inorganic	Physical
a) Summer School Attendees	60.6	69.3	63.3	69.8
b) Non Summer School Attendees	53.2	61.1	56.8	57.9
c) Year average		65.5	63.7	64.5
Year 2	**Theoretical**	**Organic**	**Inorganic**	**Physical**
a) Summer School Attendees	70.5	64.4	60.4	55.9
b) Non Summer School Attendees	58.6	67.6	60.2	55.3
c) Year average	67.2	66.5	61.5	57.5

We interviewed all the students who attended the summer school at the end of year 1, after their examinations and asked them to comment on the usefulness of attending the summer school. Here are some common themes that emerged from these discussions:

The summer school allowed us to make friends ahead of arriving at University and that helped to get us off to a good start.

It was good to experience Halls of Residence ahead of time and to spend a week getting used to Bristol.

It was very useful to go through the algebra at the start of the course and revise all the stuff we had learned at GCSE but had forgotten in the last two years. The mixture of academics and postgraduates was good and the relaxed style was good.

All the algebra we covered was important in year 1 chemistry.

We were worried about calculus and still have problems, but going through the basics and using chemical examples made it easier to understand.

The laboratory sessions were fun, they broke up the week and looking back, it was a good way to reinforce the mathematics we were covering.

There is a possibility that the summer school cohort was simply hard working and that with or without the summer school they would have done well. However, given the comments made in interview, it is clear that that week of refreshing the mathematics they knew was very important and useful. For some students it is more than two years since they studied mathematics and the first term at university can be very hard if you are trying to catch up. The introduction of calculus in the context of chemical examples, e.g. rates of reaction, first graphically then mathematically seemed to work well too.

Did this improvement persist into year 2? There was no statistical difference between the exam results of the students in the summer school and non summer school groups in year 2 in Inorganic and Physical Chemistry, with the non summer school cohort improving dramatically in organic chemistry and the summer school cohort appearing to drop down in performance (a fact that is beyond the scope of this paper). It should be noted that Physical Chemistry in year 2 at Bristol does contain mathematics, but also a fair amount of Physics. Several of the students who did not attend the summer school had taken A-level Physics, whereas none of those that attended the summer school had. However, the Theoretical Chemistry Unit is very mathematical and here the summer school attendees did exceptionally well compared with the non attendees and the rest of the Chemistry class. So had the summer school transformed these attendees into brilliant mathematicians? The simple answer is no. What the summer school did was to allow the students to hit the ground running and to take in and understand more of the mathematics they were presented with in their first year course relative to the ones who did not attend. While the latter were still trying to remember the basics, the former could concentrate on understanding new material. The first year mathematics course is an excellent primer for the theoretical course in year 2. However, previously no group from the non A-level mathematics cohort, taking this course has ever averaged a higher mark than the year average and so this result in year 2 was extremely noteworthy.

Reflections

Foster and Tall[14] reflect on the fact that less successful mathematics students will tend to cling to known procedures and have a rigid view of symbols, whereas successful students develop flexible ways of using them. Gray and Tall[15] and Saxe[16] argue that 'poor' mathematics students are simply doing a harder version of mathematics by not seeing the relationships and patterns. Boaler[5] and Lave[10] would argue that even 'successful students' sometimes cannot translate their mathematical knowledge to a new context, such as a chemical problem very easily. Skemp[17] suggests that much teaching in school mathematics is instrumental, i.e. students are shown procedures, which is easier to teach. Whereas, what is ultimately far better would be a relational approach to teaching, where students develop schema that allow them to be able to move from the starting point to the end point *via* numerous routes.

For some students it is more than two years since they studied mathematics and the first term at university can be very hard if you are trying to catch up.

Both the summer school and the first year mathematics in-house course were designed to develop a range of schema. In addition, all problems come out of a chemistry context. Students on this mathematics course often seem to find a new lease of life being taught mathematics (a subject they have generally found difficult or have avoided beyond GCSE) in the context of a subject they have generally excelled in, Chemistry. We have not converted these students into outstanding mathematicians but we have opened up to them representations in mathematics[18] that they can use more effectively than those they have learned in school. For example, a classic problem in algebra is the notion that the letters chosen are arbitrary[19] and the general ability to recognise underlying mathematics when presented in word form[20].

More data are needed without doubt to convince that a summer school can have an impact. However, there is enough evidence from the analysis of this project to suggest that it could be very effective. Not only as a refresher course, but also as a way to allow new students to get a head start and become familiar with their University setting ahead of time, even to make friends early. Such additional aspects were emphasised as being important in the end of year interviews. The latter aspect argues for a physical summer school compared with a virtual (on-line) or web-based course for students to follow pre-University, although there is evidence that these are also successful[21, 22]. However, successful web-based courses require a considerable investment of time in development[23, 24] to be appropriate and so any concept of saving time and resources by running an on-line course will only occur after some time compared with a face-to-face run course.

Run as a co-ordinated regional or national program, a series of mathematics pre-university summer schools around the country may have a considerable positive impact on Physical Sciences teaching in the U.K. Without further funding it has not been possible to run more summer schools beyond this pilot program, but is something that should be considered by HE funders.

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The physics outreach group: a how to guide

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In less than two years in existence, the Liverpool Physics Outreach Group has developed and delivered physics workshops to over 3000 school pupils.

Abstract
In less than two years in existence, the Liverpool Physics Outreach Group has developed and delivered physics workshops to over 3000 school pupils. The Group is voluntary and non-credit bearing, meeting once per week to share good practice, develop new ideas and obtain feedback on their communications skills. Funding to run projects, such as Photons in the Classroom has been awarded from the Science and Technologies Funding Council, and the Institute of Physics. After some collaboration with Chemistry and Mathematics, we have put together a business case for a School of Physical Sciences Outreach Group.

Collaboration with other Departments has begun in which we introduce students who require an understanding of physics, but often have no background in the subject (e.g. Radiotherapy). By incorporating the hands-on 'fun' elements of outreach activities, these students have found physics more accessible, and a thorough evaluation of benefits to their learning is underway. The Ogden Trust have provided funding for a Women in Physics Outreach event which will be run by girls, for girls This approach is considered effective for the recruitment and retention of girls in physics and engineering in other countries (notably Germany)[1]*.*

Benefits to our students involved include everything from a huge increase in confidence to an improvement in their motivation to learn physics. The schools involved and the Physics Department benefit from opening the lines of communication. Evaluation indicated that the pupils in all schools visited thoroughly enjoyed the sessions and have an improved attitude toward science, and in particular, physics. The uptake of Triple (separate) Science in all schools visited has increased since our visits began. We would like to share our experience of setting up and running so many successful events on order that other departments might develop their own without having to re-invent the wheel.

Introduction

The Physics Outreach Group was set up on a trial basis in May 2009, and expanded rapidly both from the perspective of student/staff participation and school interest/events which indicates a market/need for such activities. In this paper I will attempt to summarise the key considerations when setting up such a group to highlight some of the successes possible and potential pitfalls to be avoided. The approach is to look at Who? Where? When? and How? followed by Why? and What?

Who?

The potential audiences for outreach are mainly school groups on and off campus, and the general public. These can be more easily discussed in terms of where the event takes place, as the environment will influence the design of the event.

Where?

Schools

Schools are an obvious potential audience for outreach. Teachers and Heads of Physics/ Science are usually amenable to 'enhancement' activities, particularly if it links well to the National Curriculum for that level. A session will usually correspond to the duration of a lesson ~1 hour, although the teacher may wish for only part of the lesson to be used if it is the only science lesson for that class that week. The school may be willing to run a morning or afternoon of science, either for their top set in a year group or the Gifted and Talented cohort. Some schools have lessons up to 1 hour and 20 minutes long, so it is vital to confirm this before any detailed planning. If you plan to visit the same class more than once it is worth noting that school sometimes run on a 2 week, rather than weekly, timetable.

Individual classes vary in size but year 7-9 classes tend to be 25-30 pupils, while GCSE and A-level may have 15 or less. Schools are sometimes willing to group 2 or more classes together giving a larger audience of 60-100 for lectures in a school hall type setting, particularly for Science Week in March or their local 'Enhancement Week.'

On Campus
Events on campus include anything from a class visit (usually A-level), which will involve interested and highly-motivated students, usually accompanied by a the teacher who organised the event, to a family day on a Saturday where all age groups drift in with no idea what to expect. Such A-level visitors expect an experience that they cannot obtain at school, and so some time spent in the undergraduate teaching laboratories working on an experiment, demonstrated by physics students they can chat to and a tour to look at any specialised equipment in the Department are ideal.

Local museums are often happy to have activities delivered at their venue. Science Week weekends in March, half term breaks and the summer are the ideal times...

Younger class groups (year 7 – GCSE) tend to be bigger with more mixed views; some may be certain they do or do not wish to engage further with science, while most will be uncertain. Aim Higher and Widening Participation activities (usually this age range) have the aim of helping the pupils/ students to become familiar with and comfortable in a university environment and so usually show them the Halls of Residence, the Student Guild and a lecture in a formal lecture theatre. Some organisers avoid science (in particular physics) in these types of visits as the group will have mixed interests. However science is exciting, and can be controversial, which are ideal components to develop a workshop (rather than a lecture), which, when delivered by young, enthusiastic outreach group members can have a real impact.

Museums/Public Events
Local museums are often happy to have activities delivered at their venue. Science Week weekends in March, half term breaks and the summer are the ideal times, though will involve some Saturdays and Sundays. Similar to family events on campus, a lecture should have elements to keep the parents entertained as well, but you will often find that a good explanation can be taken in by those at different levels in their own way.

Museums also like stalls/stands at which small hands-on experiments (ideally supported by posters) attract passersby and you have a minute to grab their attention with something interesting and answer their questions before they move on. This also works for Careers Fairs and local Festivals which you may get invited to as your reputation grows.

Other Departments
Physics is an essential element of a degree in radiotherapy, but the students on the programme often do not have an A-level in physics, but at most a GCSE Double Science Award. In collaboration with the Radiotherapy Department, the Physics Outreach Group ran a pilot event in 2010/11 in which radiotherapy students participated in 3 non-credit bearing 2 hour workshops. Their attitude toward physics improved dramatically, and although their perception was that their understanding did not improve significantly, the results of tests (in the form of worksheets) completed individually at the end of the workshops shows marked improvement in understanding. Further the level of questions asked and their ability to reason through problems gradually increased over the course of the workshops. As failure in the physics exam in year 1 is the main reason for leaving the course, we are anxious to continue with and improve on this, and disseminate what works best.

When?
The school year runs alongside the university semesters and events can be run at any time if there is some basic consultation with the schools (to ensure not to clash with exams) and there is sufficient lead time for the schools. While a school visit can be arranged at relatively short notice (within a week, but ideally about a month in advance), many schools need sufficiently longer to ok the risk assessment, organise permission slips from parents and arrange a bus and cover (which are the most expensive parts of the exercise) for a campus visit.

The summer term from the half term in May until mid July can be a good time, but year 11 and A2 students will have left most schools. In terms of presenters, you may lose those who do not live near the university, but when the pressure of term and exams is removed, more students will often volunteer their time, encouraged by seeing their fellow students engage during term.

Who's going to deliver your outreach?
Undergraduate Students
I was concerned about using undergraduate students to deliver outreach on the basis that it would put a lot of pressure on them. However, as a voluntary project, it works quite well, as, from the students' perspective the benefits far outweigh the effort. Formally the students gain experience, which they can put on their CV while they get to know the workings of the department (familiarity with lab equipment, technicians, stores, etc.) However, they also get workshops on how to communicate their subject, practice with immediate formative feedback from staff and more experienced students, and an increase in confidence. As this is not limited to any year group the students also gain valuable experience of working in a team and acquaintance or even friendship with students in other years. From this they gain a valuable insight into what's ahead of them which can increase their motivation to master some difficult concept/skill or perspective on how much their

own understanding and skills have developed in a few short years. Through working closely with students in their final year or postgraduates, the students usually become more responsible and learn to think on their feet. However the reason they do it is usually because they really enjoy the experience and seeing the response of the pupils.

The disadvantages are that physics undergraduates are tied into timetables with high contact hours which overlaps significantly with the school term. This is also a problem for the students as their motivation can wane if they are prepared to visit a school, but their timetable constantly clashes. This can be overcome by allowing them to assist with on campus visits, even if they are only available for 1 hour between lectures. They are often happy to be involved in the preparations as well before their lectures start or in advance.

Benefits to Students
A bespoke questionnaire with open questions was completed by the initial 15 members (all undergraduates) which indicated their experience of working with the Physics Outreach Group after 1 year:

- Significantly increased confidence & experience (also useful for CV/PGCE application).
- Offered a useful opportunity to see if they would enjoy teaching.
- Inspired students to read and learn about physics other than ‘for exams.’

Postgraduate Students/Postdoctoral Researchers
Postgraduate research students and postdoctoral researchers become involved for similar reasons. Their skills can be particularly well employed in running laboratory sessions for A-level master classes or recruitment sessions. Some plan to add this as their ‘teaching experience’ when applying for lecturing posts in the future. (Note: Taught postgraduate programmes are usually too tight for time for significant involvement.)

The advantages and disadvantages are similar to those for undergraduates, but sometimes there are less problems with availability so long as the group is not reliant on asking any one student to do too much. On the other hand sometimes it is worse, as students disappear to work on an experiment abroad for weeks or months at a time. Many universities now encourage their postgraduates to engage with the Researchers in Residence programme <www.researchersinresidence.ac.uk/cms/> in which structured sessions spent in schools contributes to their credits for a transferable skills/employability module which is a requirement of their PhD programme.

Staff
Staff involvement in outreach can be in any of a huge variety of formats. A simple approach to engage staff is to invite them to give a short talk at A-level master classes or other school event on campus, thus minimising the initial time commitment. If the person has little experience they are best steered toward A-level students as they will likely have some exposure to year one students. It is important to emphasise that these students will have less knowledge (on average) than year 1 students, and perhaps indicate that a good way to avoid patronising them as an audience, while lowering the level, is to link to the applications/experiments they might be aware of in the media and to the A-level curriculum. A few minutes spent investigating and guiding them to those links with their research can be invaluable. However the catch is that as the A-level is not consistent from school to school due to different examining boards (an alien notion to many of us foreigners, so it is also worth pointing out to all staff); similar modules are sometimes taken in AS-level in one examining board while in A2-level in another.

Staff may become more involved after some positive experiences or due to interest in contributing to the enhancement of science in their child’s school. Resources such as the IOP’s Physicists in Primary Schools <www.iop.org/activity/outreach/resources/pips/index.html> are very useful as the links to the National Curriculum at each level have been clearly identified and the PowerPoint presentations and ideas for demonstrations are provided with clear guidance and timings for the inexperienced. However sending a student with them for their first session can be beneficial.

Verdict
Having a variety of providers available would be the ideal; school pupils can often associate with the students and see them as role models within reach, while staff, particularly those who work with ESA or CERN, have the ‘wow’ factor. A weekly meeting open to all, at which ideas are shared and students practice delivering presentations, running workshops activities and organising a group activity is important to develop a confidence in their skills and sense of community. Allowing the students to design a t-shirt which the Department then provides for each member of the group is also an effective method creating a cohesive group.

How?
Security Clearance – the CRB
Obtaining security clearance is not as complicated as it sounds. Usually the host institution will have some facilities through those who already work with schools such as the Recruitment Office, Aim Higher or Widening Participation. However the Criminal Records Bureau check, referred to simply as the CRB, can be obtained through the local STEMNET office (Science, Technology, Engineering, and Mathematics Network), and is transferable when someone moves about within the UK <www.stemnet.org.uk/>. The STEMNET ambassador registration and online application for CRB is short and straight forward, and they usually come to the students (preferably a group altogether) to check their documents. The first CRB can take up to 3 months to come through, although is usually significantly shorter. After that a second CRB (needed if someone has had a CRB while working for a different institution, if not a STEMNET ambassador) can take as little as 10 days (usually 2 weeks). Contrary to rumour it is a simple matter for international students (and foreign staff no matter how long or short they have lived in the UK) to have a CRB check; they are required to have the same documents confirming identity and current address as all applicants. This document is required to gain access to most schools, although you will never be alone with the pupils, and is at the discretion of the school rather than a legal issue at the moment. It is simplest to get the CRB and advise all students to carry it to all schools with them.

STEMNET
STEMNET provide a resource for schools to contact those who offer outreach or are willing to support enhancement activities organised by the school. They send regular e-mails asking for assistants or talks on particular topics for schools. This can be an advantage if undergraduates are becoming frustrated that the schools always want visits during their lengthy laboratory sessions, as some of these events are in the evenings or on Saturdays. Ambassadors commit to participating in one event per year to maintain their ambassador status, and this is recorded in the STEMNET database. STEMNET North West have consented to accept Physics Outreach Group (at the University of Liverpool) events as recordable STEMNET events so that our members can record their high level of activity. As STEMNET is a nationally recognised body, this increases the profile of their efforts on their cv. STEMNET have been very helpful, and they provide their own introductory training for all, so if there are no communications workshops available in your institution for your students, they can learn a lot from these.
Funding
A comprehensive guide on funding would fill a book, and then immediately be out of date. The following is a short summary to get you started.

HE STEM
The HE STEM programme <www.hestem.ac.uk> provides access to materials and funding to run events based on events which have been successfully run as part of pilot projects across the UK in all 4 areas. There are a of events for each subject and support is provided from them and the professional bodies; the Institute of Physics, Royal Society of Chemistry, the Royal Academy of Engineering and the Institute of Mathematics and its Applications. The call for bids to win funding to run events has been twice per year to date since launch at the end of 2010.

The Science and Technologies Funding Council (STFC) offers the *Small Award Scheme* <www.stfc.ac.uk/Public+and+Schools/1396.aspx> and the Institute of Physics the *University Schools Links Scheme* <www.iop.org/about/grants/university_school/page_38821.html> twice per year. Their websites contain clear criteria and summaries of previously successful awards from which ideas of what works and contacts can be obtained.

There are charities and other organisations out there such as the Ogden Trust <www.ogdentrust.com/> and the Science Enhancement Programme <www.sep.org.uk/> which will provide funding or support (ideas and people) to get events off the ground. However they usually expect the institution involved (the university rather than the schools) to contribute and/or funding to be sought elsewhere in the future as they have contributed to the starting up costs. Companies from international to local small business can be approached for a contribution to an established event and can be supportive, though this is time consuming.

When researchers apply for grants from STFC or Engineering and Physical Sciences Research Council (EPSRC) money can be requested in the public dissemination section to cover audiences from schools or the general public or both. An integrated approach to outreach within a department can strengthen the case for public dissemination funding.

Why
As a guide the aims of the Physics Outreach Group at Liverpool are:

- To deliver quality outreach to schools,
- To develop communication skills and confidence in students,
- To develop a resource for the department in terms of
    - A pool of trained and experienced students and
    - tested materials for and notes on how to run events,
- To increase the uptake of physics in the long-term.

It is particularly important for physicists to visit pupils in their classroom as that is where they spend the majority of their time in lessons[2] and only ~19% of the 30,000 science teachers in the UK have a qualification in physics, although not all of these will be required to teach physics[3].

The Institute of Physics commissioned research which found that students pre-GCSE already have a negative attitude toward physics, believing that the only job prospects are research & teaching, that all scientists are genius-nerds, and that they should not continue with physics as they would not be able and would not enjoy it anyway. However the main problem is that pupils are not even certain what exactly physics is[4]. Other studies done have found that pupils view science as irrelevant in their lives, see no job prospects and are not clear on which elements of science constitute physics, therefore it is not surprising that more than half of pupils asked in the OCR examining board study said that science lessons were ‘boring, confusing or difficult’[5].

Even a fantastic outreach group in every city in the country could not solve these problems, but the following is an outline of some of the benefits a group can have for the schools and their host institution.

The schools have given unanimously positive response to Physics Outreach Group activities and regularly contact us asking for more sessions and recommend us to other schools.

- Trained students can visit the classes more than once, which is not really an option for staff (for younger classes in particular).
- Students are closer in age, which is particularly relevant for GCSE and AS-level students, to enable the pupils to better relate to the presenters, very important when visiting schools with a history of low university attendance.
- Many teachers are more comfortable using the National Schools Observatory software after the class spend a whole workshop working on it under our guidance.
- More on offer both on and off campus.
- The resources are available online from our website or on a DVD by post.
- Recognised Continuous Professional Development sessions for teachers are planned for 2010/11 (after successful pilot).

Feedback was obtained from approximately half the pupils involved in the *Photons in the Classroom: National Schools Observatory* set of 3 workshops (~300 pupils). Before the presentation ~26% claimed to be interested in physics. After the workshops, 61% claimed to have 'more of an interest' in physics, 32.8% indicated 'a little more interest,' and some of the negative responses pointed out the lack of change was because they already liked the subject. When asked if the workshops gave the pupils a 'better idea of what physics is', 71% said 'yes', while 25.7% said 'a little', again some of the pupils who gave a negative response pointed out that they 'already knew about physics.'

In this survey group, the pupils were if they wanted to study Double Science or Triple (separate) Science, but it must be noted that not all pupils understood the difference and in some of the schools, the top set will automatically take Triple Science. However 40.6% of the pupils expressed an interest in taking Triple Science, which is quite a large percentage when compared to the national average of 10% of pupils in comprehensive schools taking Triple Science,[6] although the numbers have been gradually increasing since the entitlement to Triple Science took effect in 2008[8].

The benefits to the Department of Physics, it:

- Can now offer a range of outreach activities at short notice.
- Can now accept more requests for University visits.
- Has help in the recruitment of new students e.g. AS-level talk has led to requests from schools to visit the Department for the first time, which we have been in a position to organise.
- Now has experienced students to help on UCAS days and at other events.
- Now has a resources of tried and tested materials and workshops available to staff and students wishing to become involved in outreach.
- Has led to setting up the first Undergraduate Ambassador Scheme module in the University.

In terms of recruitment, although only a portion of outreach is aimed at a sixth form, the last four intakes to the School of Physical Science were considered. Of these 298 schools who sent students to Liverpool, Maths Outreach have reached 30%, Chemistry have reached 15% and Physics 10%. In total 36% have been reached by 1 or more of the Outreach teams, while a further ten schools have been reached by all 3 teams.

What

In order to tackle these issues outlined above, we particularly set out to develop workshops, which would be interactive and enjoyable, highlighting the importance of scientific research to the pupils' lives in terms of new technology and medical techniques. The idea is to develop awareness of and get pupils thinking about the scientific developments all around them. Woolnought[7] found that 'well planned visits and talks' are 'important in both encouraging pupils both to study science at school and to pursue careers in it.' This research also describes as 'likely to encourage pupils toward science' those activities which 'are both relevant to the students and intellectually stimulating.' This is achieved by using up-to-date examples from popular culture, and something familiar or local examples whenever possible (e.g. wind turbines which can be seen from the school).

Careers in physics are introduced by encouraging the pupils to think of themselves as the ones who could develop these new technologies in the future and be at the cutting edge in a challenging and important field, building on the impression, already present in younger year groups, that science offers reasonably high status, well paying jobs[9].

In order to create a more positive image of science, POG students visit the schools in pairs, and use the banter during the presentation to demonstrate that physics is a collaborative subject, not something worked on alone, in a poorly lit laboratory (an impression given in several University prospectuses in a survey commissioned by the IOP in 2007[4]).This also gives the students confidence in their early presentations, and allows the more experienced to guide the newer members. Where possible, each class is visited 3 times, usually by the same 2 students, as it was found that the impact of single-visit events falls off rapidly[10]. By the third session there is always a big welcome as a relationship has been built up with the class.

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The 3 linked workshop structure means that you can introduce quite a lot of material, but there is time for absorption and in particular for hands-on activities. In the middle session of both strands of our *Photons in the Classroom* project we use no slides, but instead focus on using the National Schools Observatory software (free to schools) in one and experiments in the other. The pupils particularly enjoy these sessions and demonstrate an improvement in their understanding from their questions and responses in the final workshops. In younger classes (up to year 9, but based on the teacher's guidance) we complete the final workshop by asking the pupils to prepare a poster with the title 'What is Physics' in small groups (2-3). These have amazed us at the links they have made between the 3 workshops, with the school science or with their own lives. Ideally these are put on the walls of the classroom/science lab for a few weeks to remind them of what they have learnt.

Our own research has strongly indicated that in classes where science is not a popular subject, their science lessons usually consist of the teacher reading out material, possibly from slides, of which they are directed to write down appropriate sections for revision notes. In our experience this happens with classes as early as year 8 and is sometimes linked to the teacher being a non-specialist in physics. Investigation has further led to the conclusion that secondary pupils' expectations at year 7 (possibly from experience at primary school or feeder school sessions) are that science will be an enjoyable, if challenging, subject with interesting lessons. They expect experiments and activities more than in other subjects and seem to be particularly disappointed when dictation is the norm. To combat this our workshops are designed to be as interactive as possible. Although we wish to provide information and visual representations (pictures, diagrams, graphs) through slides we take several steps to ensure engagement throughout the session and make even presentations more of a workshop that a lecture. It is important to bear in mind that 'teaching' them is not the role of outreach, there should be an element of fun or excitement with the aim of enthusing them about physics, which unfortunately is necessary even in early secondary school. Ideally we make the learning experience enjoyable and the pupils learn more. In our presentations:

- The slides are designed to be interesting with high quality images – lacklustre or poorly finished work is a big turn off to the internet savvy youth of today.
- Images are chosen to be of local/current interest where possible e.g. when discussing Google Earth, we always include an image of the school from the programme and ask the pupils if they recognise it.
    - The pupils are pleased we've done something specifically for them.
    - They will all recognise it, even if it takes a minute.
- The student presenters work in pairs to give it variety and introduce some banter.
- We ask the audience questions which we expect (and give them time to) respond to:
    - This breaks up the 'download' of information in one direction.
    - By varying the level of the questions, such that everyone is able to answer some of the questions, audience engagement is maintained.
    - The old adage 'Never underestimate the pleasure people get from being taught something they already know' applies to teenagers too.
- We bring props which we pass around to the entire class, e.g. in a section on space technologies we pass around a pillow made of memory foam; it is difficult to overstate the interest that this simple (inexpensive) object raises.
- We include demonstrations which involve movement of the presenters rather than just animated slides or videos. e.g. As an indicator of size in the Solar System, we have 2 balls representing the Earth and the Moon and get the pupils to guess their physical separation to scale based on the size of the balls. This is demonstrated physically and by using examples from the media such as 'Near Miss of Poisonous Comet' type headlines we can initiate a discussion of how physics is often misrepresented.
- Sections where the pupils' opinions are sought are fully integrated, with a supporting slide, where we ask the pupils to think up 3 examples of something e.g. problems facing the world. This is best done in small groups as otherwise the loudest/most confident pupils will respond quickest.
    - It is important to explain clearly what you want them to do and give them a time limit (a signal should appear on the slide to indicate the time is up), before asking them to work with the pupil beside them.
- Ideally questions are fielded whenever they arise as well as at the end, and the pupils' interests are followed to some extent, rather than sticking rigidly to the planned activity.

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Sowing the seeds of change: students taking the lead in chemical education research projects

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New and sustainable approaches are needed... in the face of the challenges posed by the new climate in UK Higher Education.

Abstract

This article outlines the benefits to institutions of engaging students (undergraduate and postgraduate) in carrying out education research projects. The activity outlined herein is probably best described as 'action research', which potentially lays the foundation for chemical education research in the future. These projects aim to identify (or develop) best practice and provide the evidence to convince occasionally cynical academics that a new approach is effective in enhancing learning and/or the student experience. The benefits to the students carrying out the projects in terms of skills development and increased confidence are discussed, along with the benefits to academics and their institutions.

Background

The landscape of UK HE is changing rapidly in the face of numerous new challenges. The introduction of higher tuition fees from 2012 is likely to increase students' expectations, while it is unclear whether or not universities will have adequate resources to deploy in order to meet the resulting new demands. In keeping with many other sectors of the economy, HE will need to deliver 'more for less'. Institutions wills face a multitude of choices with limited resources, and it is essential that waste is avoided by ensuring that changes to provision are based on sound evidence. A key challenge is that this evidence needs to be collected rapidly and at low cost, as the funding available for such research activity is limited.

Chemical education research has had a significant impact on the delivery of teaching in many institutions, with benefits for the student experience[1]. The activities of the HEA's UK Physical Sciences Centre and programmes such as 'Chemistry for our Future' have helped to bring best practices to the attention of teaching staff in a wider range of institutions than ever before, a good example being the dissemination of context- and problem-based learning activities[2]. The ability of academics to carry out such work may diminish as HEFCE cuts lead to the loss of financial support and vital communication links. New and sustainable approaches are needed in order to capitalise on the successes of the work referred to above in the face of the challenges posed by the new climate in UK Higher Education.

Case studies and methodology

Projects at Birmingham

Fourteen educational projects have been carried out by final year (BSc) students at the University of Birmingham since 2005. These have focussed on the production of web-based resources to support teaching in areas such as spectroscopy, stereochemistry, thermodynamics and kinetics (the latter two areas in conjunction with Dr Sarah Horswell). The students, having recently studied the topics themselves, are well placed to investigate any difficulties which current students encounter when studying a particular area of chemistry. They are also creative in the production of appropriate resources to supplement the undergraduate teaching, and can obtain preliminary feedback from students on the resources created. Indeed some of the students' work helped to support NMR's successful application for a University of Birmingham Teaching Fellowship in 2006.

The success of the undergraduate research projects also paved the way for the School's first MPhil in Chemical Education. The student carried out an undergraduate research project and then undertook a Masters degree examining the experiences of first year chemistry students learning spectroscopy by an enquiry-based approach[3]. This Masters degree was successfully completed in 2009 and the work carried out was instrumental in successfully embedding aspects of enquiry-based learning into the School's undergraduate curriculum.

Projects at Reading
Education projects have been offered for several years, but until recently these were mainly coordinated through the Undergraduate Ambassadors' Scheme[4]. Such projects have been highly successful and have attracted very able students, some considering teaching as a career and others who have had their fill of undergraduate lab classes and are looking for an alternative type of project.

One recent project looked into the content and efficacy of Access courses as a preparation for higher education. The project was carried out by a mature student who entered HE through the Access route herself and had struggled to fill the vast gaps in knowledge between her prior experience and the first year chemistry course. Her findings have been eye-opening and have confirmed the apprehensions most Admissions Tutors have about making offers to applicants with Access qualifications. In the project the student looked at overall success rates in different HE courses, including the physical sciences, of students entering with Access qualifications. The Department has changed its admissions literature regarding Access courses as a result of the findings.

...education projects should not be seen as a 'dumping ground' for less able students, or those who don't perform well in the teaching laboratory.

Education projects are becoming a mainstream choice at Reading as colleagues in the Department's recently formed Chemical Education Group become more confident in supervising and assessing them.

Projects at Southampton
Educational projects had been under discussion at Southampton for a number of years so that more choice could be offered to final year students at a time when student numbers had increased significantly. The first student to undertake such a project was an individual who put themselves forward for the role, having being a vociferous contributor to the evaluation of teaching innovations that had been implemented in previous years. The outcomes of this student's project on 'Lecture Capture' were published in 2010,[5] and have been the subject of numerous presentations, several by invitation[6]. The student involved is currently undertaking a Masters in Chemical Education Research, and will shortly begin a PhD in this field.

This success gave us the confidence to offer projects in 'Education and Outreach' alongside those in our other research areas for the 2010/11 academic year, which led to the recruitment of 9 final year BSc project students. Although a number of these students have worked on outreach or school-level education research projects which are beyond the remit of this article, some have focussed on education research related to our own delivery, an example being research into the effectiveness of sharing learning outcomes with students at HE level[7]. The high profile of the work undertaken in this period has increased the demand for such projects among students in subsequent year groups.

The benefits and the pitfalls of education-based projects
Academic colleagues who have limited experience of chemical education research don't always appreciate the value of such work, which has a number of consequences for those involved in educational development. A key factor is the reluctance of many staff to accommodate change that isn't perceived to be based on solid evidence. Successful research projects can actually provide evidence that has a transformational impact, as in the case of the 'Lecture Capture' project at Southampton which has led to the majority of first year lectures being recorded in the 2010/11 academic year.

Many students decide at an early stage in their degree that a career in a research laboratory is not for them. While many of these students relish the opportunity to test themselves in the lab as part of a research project, others would prefer to turn their hand to a project in an educational context. Such a project may allow them to develop the skills required for a particular career (e.g. teaching), or to develop other specific interests. Of course, it is vital that these students are reminded that this may be their only opportunity to carry out lab-based research, and they should make this decision only after careful consideration. New graduates typically face interview questions about their final year project, particularly when applying for science-based jobs, and a lack of lab experience may be a hindrance to some. However, one education project graduate commented that during her interview for the British Transport Police the panel could understand far more about her project than they would have about any chemistry-based research. She attributes the skills she developed in her project and the opportunity to talk about the work to her success in securing the position.

Many chemistry departments have experienced a significant increase in numbers in recent years, making it more difficult to accommodate project students in research labs. As such, it is challenging to provide comprehensive supervision, which can impact upon the student experience as well as creating safety concerns. By offering an alternative to those students who would like to do something different, it is possible to alleviate those pressures a little. A key caveat is that education projects should not be seen as a 'dumping ground' for less able students, or those who don't perform well in the teaching laboratory. Research in education is more closely related to social science and requires a particular approach and a degree of dedication. As such, unmotivated students or those without the appropriate skills set are unlikely to generate positive outcomes, and can potentially do more harm than good.

Many departments have academic staff or teaching specialists with an interest in education research, and these may be the ideal supervisors for such project students. They may already have a sense of the requirements of this sort of work, and a team of project students can assist them in achieving career objectives that would otherwise be out of reach. Funding for such work is scarce and undergraduate project students may be the only individuals available to do the 'legwork' required to collect and verify the evidence that underpins any piece of research. In cases where supervisors have no background in education research, it is essential that they are supported by colleagues who do, with particular attention paid to marking criteria and moderation.

Projects based in education can be all too readily dismissed by some of the more 'traditional' members of academic staff who view the final year project more as a rite of passage than a preparation for real-life problem solving. Although educational research is more closely aligned to social science research rather than laboratory-based research the scientific method is still at the heart of the investigation. Education projects are designed in exactly the same way as scientific research projects starting with a hypothesis, followed by a plan of attack. An appropriate method for collecting results is designed and the results subsequently analysed. From this an evaluation of the method is made and conclusions drawn. Written reports of projects follow similar structures independent of the nature of the research and the lab note book can be replaced by a log book of activities, literature searches, records of results etc. In fact mark schemes are fairly transferable from one type of project to another, and it is quite feasible that academics without any prior experience of chemical education research could provide adequate supervision of such students.

Conclusions

The evidence shows that it is possible for students to undertake research projects in the area of chemical education at HE level that are successful and have a long-term positive impact on the student experience and the delivery of teaching. The outcomes arising from such projects will be of great value as students begin to demand more from their university teachers in return for their increased fees. Although the 'mind-set' required to carry out educational research is quite different from that needed in the chemistry lab, there is enough support available in the literature for any interested and dedicated academic to turn their hand to such research. As well as relieving pressure on space in research laboratories, educational projects allow students to develop a different range of transferable skills when compared with laboratory-based projects. This is particularly valuable in an era when undergraduates are keen to maximise their skills development during their studies[8].

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The trials and tribulations of designing and utilising MCQs in HE and for assessing forensic practitioner competency

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Abstract
Multiple Choice Questions (MCQs) are a very well known, traditional and accepted method of assessment. The use of MCQs for testing students has produced numerous debates amongst academics concerning their effectiveness as they are viewed as practical and efficient but also perceived as possibly 'too easy' and potentially unable to appropriately test the higher order cognitive skills that essay questions can assess.

The use of MCQs in a forensic science context is currently being investigated, not only for use within forensic science education, but also for the testing of competency of qualified forensic practitioners. This paper describes a Higher Education Academy funded project that is investigating the design and the implementation of MCQs for testing forensic practitioners and the lessons that have been learnt so far, that will assist academics in the development of robust MCQ assessments within forensic science degrees to promote and assess deep learning.

Multiple Choice Questions (MCQs) – Friend or Foe??

Multiple Choice Questions (MCQs) are a type of objective test question which involve an answer(s) to be chosen from a list of possible responses[1]. MCQs are commonly used within physical sciences education for both summative and formative assessments as they are a practical and efficient means of assessing large groups of students[2]. Much research has been completed upon MCQ use, design, management and implementation and due to this there are an abundant amount of resources that can be used by academics if they wish to use this type of assessment within their own teaching.

There is a large body of research into MCQ design, for example, studies completed by Carneson *et al.*[3], Shultheis[4], Fellenz[5] and McCoubrie[6]. Within this literature there have been attempts to produce guidelines for academics in the production of MCQs[1,7,8].Studies by Collins[9] and Lorusso[10] discuss the importance of constructing questions which reflect the material being taught, using consistent writing styles and the correct construction of the stem (the question or statement that leads to the possible answers) and the options (the choices of possible answers which include the correct option and the incorrect options, also known as distractors). In addition to the construction of the MCQ test, the important issue of marking schemes is also well documented in the literature. Whilst standard marking systems (where a correct answer is awarded one point and these are totaled for the final score) are still very popular, alternative scoring processes such as negative marking, confidence based marking, the 'hedging' format and value exam format are available to reduce guessing and encourage participants to identify their level of confidence in their answers which promotes deep thinking[11,12].

A key debate within MCQ use is the reliability of this assessment method, with critics claiming that they are 'too easy', they allow students to pass through guesswork and do not test higher order cognitive skills that other assessments such as essays and laboratory write-ups are able to[5, 13]. Although these comments are relevant, there are published ideas and methods that address these issues. Bloom[14] in 1959 published a taxonomy of hierarchical cognitive learning which is regularly used by MCQ designers to test knowledge, comprehension, application, analysis, synthesis and evaluation. Bloom's Taxonomy is commonly simplified to just three levels; knowledge (the easiest MCQs to construct), combined comprehension and application (understanding the meaning of material and then being able to apply it to concepts and theories) and problem solving (transferring existing knowledge to new problems and situations)[14]. With this in mind, MCQs can now be designed to assess a range of different module objectives beyond just the recollection of facts.

The use of MCQs in a forensic science context is currently being investigated, not only for use within forensic science education, but also for the testing of competency of qualified forensic practitioners.

MCQs in the Field of Forensic Science

With the number of students reading for a forensic science degree having increased over the past 5 years[15, 16] the need for efficient assessment methods has become essential. In forensic science teaching, a range of assessment strategies are used, including practical activities, seen and unseen exams, laboratory write-ups, portfolios and research projects. Varied assessment schemes seen in forensic science degrees are generally due to the diverse and practical nature of the subject. To effectively assess students in this subject, MCQs must include skills such as problem solving, application of forensic principles, evidence interpretation and understanding of forensic techniques. At Staffordshire University, before the initiation of this project, MCQs were used as a formative assessment only in year 1 and as generally only 'in lecture' quizzes or online Blackboard self-assessments beyond this level. When looking at the type of MCQ being utilised at Staffordshire University, the majority tested knowledge only with only a few exceptions that assessed comprehension. A typical example of a knowledge based MCQ being used is:

What is the common term used to describe marks that are invisible until chemically or physically developed?

- Latent
- Patent
- Obscure
- Concealed

This MCQ is purely asking the student to remember the meaning of the word 'latent' in terms of marks found at a crime scene, this is obviously important but does not reflect the skills needed of someone involved with mark development or interpretation. An MCQ that asks for this deeper thinking could involve a description of a scenario in which a fingermark is present on a particular object and then ask 'what is the best method for enhancing a mark on this surface?" This would then require the student to have knowledge of latent marks, the development techniques available and their relative effectiveness and to then apply this knowledge for this particular scenario. Although care must be made in the construction of this type of MCQ, for example, to make sure that the stem is clear and contains all the relevant information needed to correctly answer the question and the distractors are all plausible and accurate but do not fully meet the criteria for the correct answer, the production of these are not too onerous[9]. Problematically, the nature of forensic science is that many crime scenarios involve complex relationships between evidence, require research to answer particular questions and interpretation is generally not straightforward; therefore a more sophisticated set of MCQs is required.

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The generation of questions which feed from one or more particular crime scenarios, that combine evidence, procedures and ideas and require the student to have completed research prior to their answer are recognised to be time consuming to produce[17]. Currently, there are no protocols or 'toolkits' for the production of MCQs specifically for forensic science topics. Although there are readily accessible databanks of MCQs for other subjects, such as Question Bank[18] and OCTAVE database[19] (for veterinary science education), there is no 'example bank' of forensic science related MCQs available for academics to use. This current project ultimately aims to develop a series of resources (a 'toolkit') for the development and implementation of MCQs for academics that teach forensic science to undergraduate and postgraduate students. These resources will include the generation of a bank of example MCQs, guidelines for MCQ management and an associated workshop in the design and implementation of MCQs in forensic HE assessment. To enable this, contribution to a large scale MCQ testing scheme for forensic practitioners was carried out and observations made upon the potential problems that can be encountered when designing MCQs in forensic science topics.

MCQs for Competency Testing of Forensic Practitioners

There is a widely known need to ensure that the quality of forensic and expert evidence is of a suitable standard. 'Competency' is a key performance criterion within the forensic investigative process for all forensic practitioners and proving competency in a UK Court is an important aspect of the legal system. There is currently a government initiative for improving employee skills, including in the scientific community[20]. Many professionals within the forensic arena have a variety of qualifications but they all need to demonstrate 'continuing professional development' and continuous professional competency. Since the Council for the Registration of Forensic Practitioners (CRFP) ceased operating in March 2009, there has been an imperative to provide a quality control system, which will help maintain public confidence in forensic practice in the UK and to provide assurance to the UK Criminal Justice System. This is especially important for forensic practitioners that are from smaller laboratories that do not have ISO standard accreditation or who are infrequently required to act as a forensic expert due to the very specialist nature of their expertise.

Where the CRFP essentially based their accreditation of forensic experts by peer review, a new method for assessing competency in forensic experts has been developed by the Forensic Science Society (FSSoc), which includes a pre-assessment evaluation of the practitioner, a practical based proficiency test and an MCQ test[21]. As the outcomes of such assessments allow a practitioner to describe themselves as competent, the MCQ tests were required to be a robust assessment strategy that allowed the level of knowledge and understanding across a broad range of forensic science topics to be identified and quantified and allow the use of learning outcomes and assessment criteria to provide quality assurance and academic rigour. The quality assurance of such tests was of upmost importance which highlighted the mechanisms required for MCQ test management and implementation.

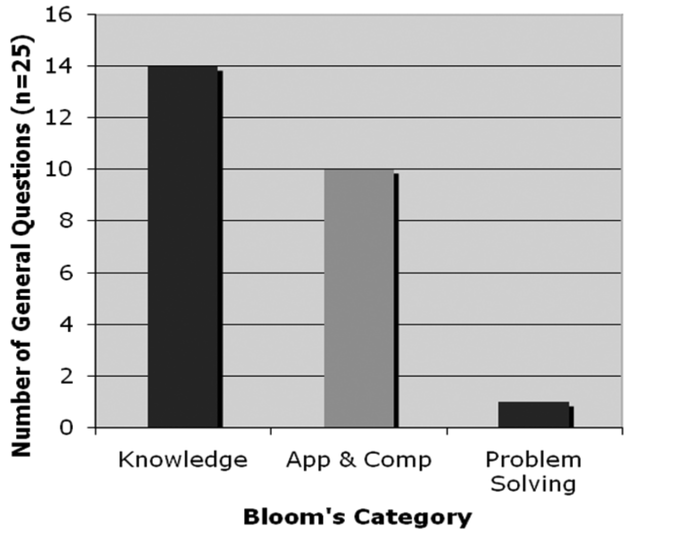

Figure 1: Number of general forensic science MCQs testing the three main levels of Bloom's taxonomy

The aim of this paper is not to discuss the competency of forensic practitioners but to utilise the initial experiences of implementing a pilot testing scheme for practitioners to identify issues involved in designing and managing MCQs particularly in forensic science topics and to identify any considerations required to use MCQs to test higher levels of learning in students studying forensic science in HE.

MCQ Testing the Experts

The main purpose of the testing scheme for forensic experts is to get a rounded-view of the competence and professional understanding of applicants as forensic practitioners in their various specialisms. Consequently, MCQs do not represent the full assessment process as prior experience and practical abilities in using particular equipment and methods also need to be considered. This project has only focussed upon the MCQ element of assessment therefore no evaluation of any other parts of the process have been considered. Two rounds of MCQ testing were conducted for forensic podiatrists in the UK; a pilot test and an actual test. The MCQs used for both the pilot and actual test consisted of 25 MCQ questions covering general principles of forensic procedure, evidence interpretation and relevant legal issues and 25 MCQ questions covering subject-specific topics relating to the relevant specialism of the applicant, in this case forensic podiatry. The general questions were all designed to primarily test knowledge and application/comprehension whereas the subject-specific MCQs were designed to focus upon problem solving. The participants were informed that for each correct response they achieved one mark but for each incorrect response, half a mark would be deducted. As part of the quality assurance process each MCQ was reviewed by three MCQ developers from the Department of Forensic and Crime Science at Staffordshire University and FSSoc. The final test formats were checked by a committee within the Forensic Science Society. The pilot-testing scheme was carried-out on two forensic practitioners. The second MCQ test was implemented in the same format as the pilot test but with revised and validated questions and was completed by four forensic podiatrists. The small number of participants was partly due to the small number of forensic podiatrists practicing in the UK. Forensic Podiatry was the initial specialism used, as experts from this area of forensic science are usually not affiliated with an accredited laboratory and therefore require other means to show competency such as the MCQ testing scheme being discussed in this paper. Feedback from the participants was gathered by one-to-one interviews and focussed on their understanding of the questions, their thought processes on choosing their answers and their opinions on the appropriateness of the MCQ format. This was to gauge whether the design of the questions tested beyond just knowledge and had climbed up Bloom's ladder of hierarchy of educational objectives[14] and to understand how MCQs could be used to encourage deep learning. The 25 general MCQs were also investigated in terms of which levels of Bloom's ladder of hierarchy were addressed and whether there was any difference in the participants' performance between these different levels.

For the purposes of question confidentiality, only general descriptions of the questions used are given to allow the feedback from participants to be understood.

Observations from the MCQ Test Process – Lessons to be Learned

Development of Learning Objectives for Testing Competency in Forensic Science Skills

Prior to the generation of the MCQs for the testing scheme, learning outcomes were required. As stated by Collins[9], these learning objectives should be written in terms of specific learner behaviour and should define the important skills and knowledge required to be tested.

When defining this knowledge, it must be clear to the examiner what a forensic expert must know to be considered as an expert. For appropriate MCQs to be generated this knowledge must be unambiguous but in the world of forensic science, there are grey areas of knowledge that require some experts to understand but not others. Consequently, instead of defining specific facts that must be known, the learning outcomes were directly linked with Bloom's taxonomy[14] and described in terms of what an expert must demonstrate in general and subject specific knowledge, comprehension, application and problem solving within a forensic science context. This is also an effective way to test specific areas of forensic science with HE students as with many areas of evidence analysis, due to their practical nature, the ability to show the levels of learning stated in Bloom's taxonomy is much more important that just testing students' factual knowledge of the evidence.

MCQ Design for Forensic Science Topics

When designing the MCQs, it became apparent that a designer should *not* become bogged-down with attempting to make every question test higher cognitive levels. There is a tendency, once fully aware of the potential to test skills such as problem solving, to design all of the questions to meet this level. In reality, the level must take into account the subject matter as well as the level of understanding that is required from participants. For example, the general forensic science questions in the pilot test were centred mainly on factual issues such as expert witness duties, continuity of evidence and court conduct. As stated by MCQ researchers such as Glaser[22] and McCoubrie[6], to ascertain expertise in this type of general area of forensic information, demonstration of pure knowledge of a domain is '*the single best determinant of expertise.*' Figure 1, shows the number of general MCQs testing knowledge, application and comprehension and problem solving.

As stated above, the majority of questions were knowledge based only, which was appropriate for the topics being tested, but to enable a participant to demonstrate their understanding of certain forensic procedures and protocols, MCQs designed to test application and comprehension were also incorporated. These questions invariably asked for the participants to evaluate certain court case scenarios and evidence handling ideas and identify which was 'the best' or 'most appropriate'. In these types of question, all of the options are correct but the participant must use their court going/court report writing experience to identify which is the preferred answer. In addition to these questions, a problem solving type MCQ was also included which described a particular scenario and then asked the participant to use their knowledge and experience to evaluate the best course of action. The success of the four participants in these different question types was variable. Figure 2 shows the percentage number of correct answers for each of the four participants in each of the knowledge, application/comprehension and problem solving questions.

It is apparent that each of the four participants performed the best in the lower level of Bloom's taxonomy[14], with all participants correctly answering 50% or more of the

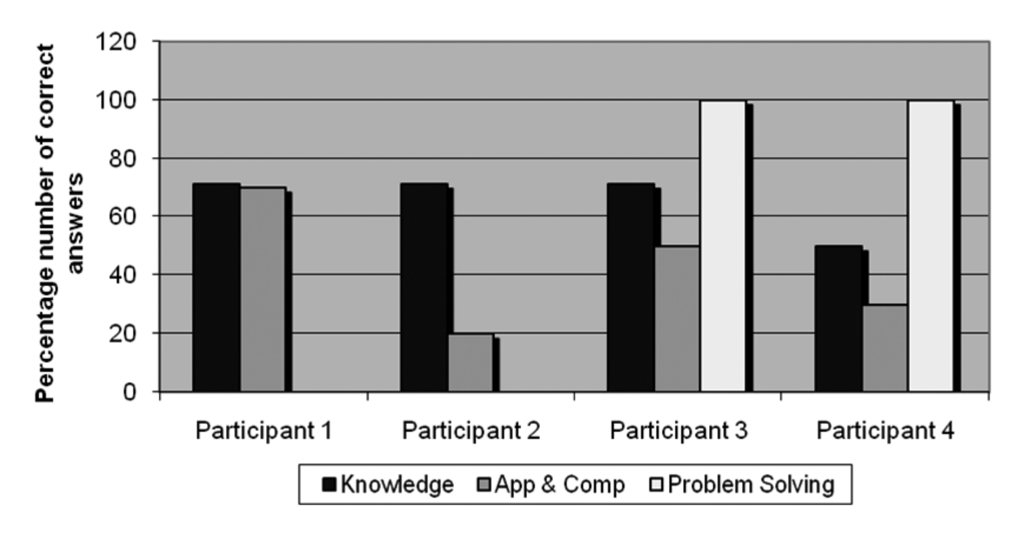

Figure 2: Percentage number of correct responses for each participant for the knowledge, application/comprehension and problem-solving MCQs

knowledge based MCQs. No real trends can be determined from the higher level problem solving MCQ as there was only one question of this nature in the general forensic science topic test but it was clear that this question was possible to answer with two participants giving a correct response. The most interesting results were seen for the MCQs that tested application and comprehension of knowledge. Although participant 1 performed very similarly in these questions, the other three participants were not as competent. This could have been due to the subjective style of some of these questions which lead to participants interpreting the question in different manners. This could especially be seen in questions that asked for the participant to use their own experience of court cases which may have differed. Of course, it is also possible that these questions have accurately depicted the participants' competency in this topic, where they all have sufficient knowledge of the topic but differ in their ability to fully comprehend some of the forensic processes being questioned. Some of the design features of the MCQs that could have contributed to the participants' performance in application and comprehension are discussed below.

With the subject-specific questions, the emphasis was to test the skills in which an expert would need to be proficient to conduct analyses and interpretation of a particular evidence type. For this, the lower level learning was inadequate, as this would not demonstrate a forensic scientist's ability to use particular information to answer bigger questions about a crime scene or evidence. The subject specific questions were a mix of knowledge, comprehension, application and problem solving, many of which provided a case scenario with relevant information and then a series of questions that were related to the crime and evidence. The main difficulty identified when designing MCQs that provided a lot of prior information as part of a crime scene scenario and are lead-ins for more than one question, was to avoid producing questions that cued a response to subsequent questions relating to that crime. Careful writing of the stems and ensuring that each question is as independent as possible reduced the risk of giving the participants 'clues' to the subsequent questions. The effect of cueing has also been discussed in MCQ use for clinical nursing practice, which also attempts to provide 'real-life' scenarios to test participants' higher learning skills[23]. Test timing must be increased for this type of question as the participant has a large amount of material to read (and *re-read*) before making a response. This type of MCQ could be expanded further, instead of only providing a case summary or a description of the evidence, photos of exhibits or even video recordings, e.g. simulated CCTV scenarios, could be used as a lead-in to the questions.

If this type of question was used for HE students, the resources such as photos and video recordings could be provided to the students prior to the test so that they can carry out analysis and research on the evidence to prepare for the MCQ assessment. Research conducted by Williams and Clark[24] observed that students rated the effort they exert before an MCQ test higher than their actual ability or teacher input. This study showed that students perceive their input towards the preparation of an MCQ test, such as note-taking, reading etc as being very important leading to deeper learning prior to the tests. By providing case scenarios and information about forensic evidence before MCQ tests, this will encourage the desired deeper learning as an outcome.

The participants in the pilot study were able to provide insight into the thought processes of a student when deciding which option to choose in an MCQ. These thought processes are highly important in aiding an MCQ creator in the identification of potential pitfalls in question design.

When creating a stem for an MCQ that asks for 'the best' or the 'the most important' option to be chosen, it became apparent that the designer must be aware of the affect of any differences in the participants experiences in their ability to choose the correct answer. For example, on a question relating to laboratory procedure, one participant stated

> *"I struggled with 'the most important reason' aspect of the question as I could see that some other options offered as being rather important too"*

It appeared that in some situations, distractors can appear appropriate in their balance of plausibility and not fulfilling the criteria for the correct answer to the MCQ producer but depending on a participant's experience, for example, work place protocols, the same balance is not seen by the participant. Awareness of differences present in the forensic field is essential for this balance to be true for all participants. The idea that options should not be biased towards a particular group of people due to their background has been discussed by Collins[9].

One general question asking what the functions of a particular forensic science body were, caused issues as the options indicated the answer should be the body's main 'concern' rather than depicting the main 'role' which the participant had memorised. They stated;

> *"I struggled with this one a bit. I went for option (a) as the described 'role' of this body represents half of option a, but I would not have considered the second part of this option as being correct, therefore I am not 100% confident in my answer because of this"*

The problem with this question appeared to lie not only in poor stem wording but also in the fact that the question had different possible answers depending on how the participant interpreted the published information (readily available to forensic practitioners) describing this particular forensic body.

In these situations, if appropriate, the wording of the options must fit with the stem or this type of question should be avoided completely if there is not solely one answer. Keeping in mind the possible ambiguity of some areas within forensic science, the choice of question is highly significant. Although the participant had reduced confidence in their answer, this did not stop them making a response even though there were penalties for incorrect answers. In fact this participant described themselves as having a lack of confidence or doubt with 10 out of the 25 responses he gave to the general MCQs but still attempted all questions regardless of the negative marking. This shows that negative marking is potentially only a deterrent when the participant has no idea of the answer at all and an element of 'hedging one's bets' occurs when the participant can narrow it down to two possible answers.

MCQ Management

When designing MCQs that must potentially stand-up to scrutiny in a UK Court, any quality assurance procedures used must be transparent and easy to follow by those considering it. When designing the MCQs for the forensic practitioners, it became apparent that when there are a large number of questions that need to be reviewed and updated by a group of designers, a continuity trail is desirable. This trail can most easily be provided by utilising a database which states any changes to questions that have been made, the name of the designer making the changes and when and how the questions have been used. In HE, a MCQ database containing forensic questions would benefit from the ability to be updated by multiple designers and to audit the evolution of questions over time. This is especially useful when showcasing a course's assessment methods to University External Examiners. From these observations a software programme which provides a useful interface linked to an MCQ database has been designed and created. This software programme combines both a testing facility and also a management system. It allows the user to not only store and search for MCQs based on topic, type and level of cognitive thinking being tested, which is similar in style with other extant databases of MCQs but also allows the evolution and quality control procedures to be viewed for each individual question. The programme allows multiple users to view developing MCQs and provide revisions and comments regarding design and validity, all of which is logged providing a trail of continuity. Multiple Choice Question tests can also be created using the software, similar to using the test function in Blackboard but in this case, the test creator is not limited to the structure of Blackboard and can make bespoke tests for different purposes without the need for copying and pasting MCQs from other areas. This is particularly useful for HE institutions who deliver bespoke courses to external companies. This software programme is currently being piloted at Staffordshire University and the FSSoc but will be made available to HE institutions in the future.

Conclusions

The generation of a 'toolkit' in MCQ design and implementation is a useful resource for academics wanting to use this type of assessment in their teaching. This toolkit could be developed from observing MCQ use in other disciplines but this project has also utilised the experience of developing a professional competency testing scheme for forensic practitioners. Observing an MCQ testing scheme for forensic practitioners to provide information and ideas for academics has been invaluable. Higher Education is constantly aiming to develop assessment types which are not only robust but also so that their actual creation may be mapped in terms of quality control and validation. In examining a system which must be sufficiently robust to stand up in a court, the smallest details in design are crucial, and therefore most useful for academics trying to create MCQ tests for students. This preliminary study has identified test design issues that must be considered by academics when developing their own MCQs and has also been invaluable for the initiation of the MCQ 'toolkit'. A limitation of this study has been the small cohort of participants that took part in the tests

MCQs... can be robust if designed with knowledge of the requirements of the expected audience and of the design philosophy of MCQs which appropriately test hierarchical cognitive learning.

to date. This project will develop as further MCQ tests are generated for the FSSoc in forensic subject areas other than forensic podiatry. Feedback from future participants will be gathered and analysed for subsequent publication and ideas and issues raised incorporated in the final MCQ toolkit. Currently, the toolkit has been initiated by the creation of example MCQs in a range of forensic topics for academics to use within their teaching. Further to this, an MCQ design and implementation workshop will be delivered at Staffordshire University in September 2011.

As an assessment process for forensic practitioner competency, MCQs have demonstrated that they can be robust if designed with knowledge of the requirements of the expected audience and of the design philosophy of MCQs which appropriately test hierarchical cognitive learning.

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In examining a system which must be sufficiently robust to stand up in a court, the smallest details in design are crucial, and therefore most useful for academics trying to create MCQ tests for students.

Making better and wider use of undergraduate teaching laboratories in the support of chemistry in the UK

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Abstract

The Chemistry Departments at Bristol and Sheffield Universities have adopted two complementary approaches to maximising the use of teaching laboratory space, in the main to support secondary school level study. The two approaches involve the adaptation of a small part of a teaching laboratory or the use of the whole of the undergraduate teaching laboratories themselves. In the former case a small number of students can enjoy their use throughout the week and in the latter a large number of students can use the facilities one day per week in undergraduate term time and in the remaining 18 weeks of the year when not required for undergraduate teaching. This paper describes the development and the challenges to be overcome with both scenarios and the advantages and disadvantages of both approaches, using an example from each.

Introduction

Many UK chemistry departments admit secondary school students to their teaching laboratories on occasions throughout the year, whether it is part of a school spectroscopy visit for Post 16 students[1,2] for chemistry competitions such as the Royal Society of Chemistry's Top of the Bench and Analytical Chemistry competitions or the Salters' 'Challenge'. Some chemistry departments use their facilities as part of summer schools such as the Salters' Camps[3] and for Widening Participation[4,5] activities such as those run for the Sutton Trust[6]. These engagements are put on as a collective desire to promote chemistry, to assist local and regional chemistry teachers by providing practical opportunities that are not possible at secondary school and as part of the promotion of the advantages of Higher Education generally. Some will undoubtedly use such activities to promote their own departments[2]. Historically such activities would be delivered with little funding, by committed individuals, whether academics or postgraduate students, and involving small numbers of students per year.

Outreach at Bristol ChemLabS

Since the creation of Bristol ChemLabS in 2005 it sought to establish a wide-ranging programme of public engagement, in addition to providing state-of-the-art professional-standard teaching laboratories. The laboratories were equipped with research-grade instrumentation with embedding of e-learning and e-assessment alongside more conventional teaching methods to improve undergraduate student experiences[7,8]. As part of this project a secondary school teacher joined the staff with the main aim of utilising the School of Chemistry's facilities for outreach regionally, nationally and internationally, as well as to provide congruence in teaching between secondary and tertiary level Chemistry[2,9-11].

There are two floors of teaching laboratories at Bristol, each can accommodate 108 undergraduates doing individual practical work, with no separation between organic, inorganic or physical chemistry based experiments. It was a long-standing desire of the Outreach team at the School of Chemistry at Bristol to utilise the teaching laboratory space more frequently, when not being used in undergraduate teaching. Clearly, these facilities could be used to both promote and support the teaching of chemistry at secondary school level and to the general public and could possibly be used to generate an income to keep the laboratories up to a very high standard[2,12]. There are about 18 weeks per year when schools are in session and undergraduates are not using the labs either because the undergraduates are at home or in examinations. In Bristol, the labs are also not used on Wednesdays. This leaves plenty of time when school groups could use them quite apart from the times when they are used to host summer schools and day activities in some of the school holiday periods.

It was a long-standing desire of the Outreach team at the School of Chemistry at Bristol to utilise the teaching laboratory space more frequently...

The School Teacher Fellow at Bristol, working with technical staff and the Outreach Director, drew up a portfolio of practical activities that could be carried out in the labs for secondary students from all years, and resourced and trialed them early in the history of the Bristol ChemLabS project. The favoured practical activities, those that could not be done in schools (e.g. because of a lack of sufficient equipment such as fumehoods, because of a lack of experience or simply because of timetable constraints) were then up-scaled. The 'standard' practical work on offer for Post-16 students naturally involves organic chemistry as the amount of equipment in schools cannot match that available at a university. The extraction of caffeine from tea bags, which involves electric heating mantles, Buchner filtration, cooling in ice-baths, solvent extraction and rotary evaporation with infrared spectroscopic analysis is one favourite. Up to 80 students working in pairs can be accommodated. A second organic practical is a more involved synthesis of a solid anaesthetic, which also includes thin layer chromatography and melting point determination. Other practicals provided for younger students include circuses of polymer experiments, colour chemistry experiments and green chemistry. Perfume chemistry workshops for primary aged students in years 5 and 6 (10-11 year olds) are also organised as are practical sessions supporting large numbers of students for pre-university assessed (examination) work and several teacher requested/bespoke sessions.

All outreach practicals use glassware specifically set aside for schools work so that there is less time taken up with changing over from undergraduate practicals. To engage with large numbers of students in one sitting requires the training and payment of a large number of postgraduate chemistry demonstrators. Bristol normally staffs engagement activities at a ratio of 12 students to one demonstrator and we will also have the School Teacher Fellow and technical staff on hand. If accompanying teachers wish to participate in either the experiments or in the demonstrating of the experiments this is encouraged. It is not unusual for visiting groups, sometimes from 3 or 4 schools per session, travelling up to 2.5 hours for a day visit, to make a full day of the visit by enjoying talks and a lecture demonstration in the afternoon; some of the talks being presented by postgraduates. Autumn, Spring and Summer schools see students and school groups regularly arriving from Ireland, Malta, Spain, France and Italy with schools in the Far East considering participation in coming years.

Of the 25,000 - 30,000 students engaged directly by Bristol ChemLabS outreach per year, approximately 2000 per year work in the labs. The organisation of this requires considerable technical, secretarial and other support from the department as well as a large contribution of time from postgraduate volunteers. The latter are not only financially rewarded but also gain considerable soft skills much in demand by employers[13]. This is managed sustainably by charging for activities at full cost whether directly to the schools, through Impact requirements of research grants, specific outreach grants or donations by alumni[12].

Part of the success of Bristol ChemLabS Outreach is that specific practical sessions are available from one year to another and the quality of the student experience is consistently high because of stability of lead staff and the standard of training of the postgraduates. In addition, school teachers know that the STF is a well respected teacher and that the experience will map well to not only the formal curriculum but also the wider aspirational goals of any visit. The scaffolding provided by the STF for any visit, in terms of preliminary material sent to teachers (health and safety information, practical scripts etc.) has maximised the impact of any activity[14-16]. Although it was not an objective of the project, undergraduate recruitment has been influenced positively by the open labs project[17]. The sharing of best practice with groups from other countries has been an extremely beneficial facet of this project. Having colleagues from other countries sharing their best practice with us has only enhanced the experience for Bristol Undergraduates and the schools we have engaged with.

Challenges faced by Bristol ChemLabS outreach include:

- Matching the demand for spaces during undergraduate term time.
  There is of course a natural limit on the number of places available to use the laboratory during term time and this is an inevitable draw-back of the Bristol ChemLabS approach.
- Impact of the 'rarely cover' policies in schools.
  In order to combat this we run competitions in the evening. However, to do this on a regular basis puts too much strain on support staff that have to give up evenings.
- Convincing some funding bodies that the number of students we can work with in the promotion of chemistry is realistic and not a flight of fantasy.
  This is an area that continues to frustrate.

The immediate future for Bristol ChemLabS is that the laboratories will continue to be used in this way for at least the next three years but with no end in sight. A business plan was written to cover this timescale and despite the economic downturn (which was a factored contingency) the plan is working very well. The development of the use of the laboratory space by an increasing number of residential schools both by school students and for teacher training is set to increase. At the time of writing the bookings for the laboratories are 11 months in advance.

University of Sheffield Schools Laboratory
The USSL project involved the creation of a small (up to 15 students plus teachers) high specification laboratory which opened in November 2007. Here groups of students could carry out practical work that was not normally carried out in school or college. The laboratory possesses six large, high specification fume cupboards under which is stored a comprehensive range of apparatus.

A little used laboratory in the heart of the undergraduate teaching laboratories was selected for conversion into the dedicated facility. This central position was chosen as it would allow visiting students to gain a sense of what undergraduate students experience during the practical aspects of their course. The large sliding doors to the USSL were constructed entirely from glass designed to create a sense of being amongst the 50, or so, undergraduate students within the larger physical chemistry laboratory.

It was felt that school and college students would benefit from access to a dedicated university facility in which they could have the time to develop their practical skills and knowledge beyond what was normally possible in school. The constraints upon practical work range from the prohibitive cost of chemicals or the perceived risk of carrying out certain reactions through to the simple fact that students rarely have the chance to have several hours in a lab in any single session. Furthermore, the experience of being in a university department, alongside undergraduates and postgraduates, was expected to have a motivational effect in terms of their consideration of university education and, more specifically, on their choosing chemistry.

To achieve our objective, funding was provided by NESTA and by the Royal Society of Chemistry through the Chemistry for our Future (CFOF*)* program[18] (Strand 4, Widening Schools' Access to University Laboratories.). This funding allowed the University of Sheffield to create the 'nuts and bolts' of the University of Sheffield Schools Laboratory (USSL). The majority of staffing costs during the first year of the USSL were initially borne by the RSC, again through the CFOF program (Strand 2; School Teacher Fellowship). Will Davey, one of the RSC School Teacher Fellows (2007/2008) was appointed to the Department of Chemistry. One of his objectives was to use his expertise as an experienced chemistry teacher at a local Sheffield secondary school (King Edward VII School) to develop and deliver relevant practical work to students from KS2-5. Initially this involved him equipping the laboratory with the necessary apparatus and appropriate chemicals. A number of companies and organisations were keen to help support the creation of the USSL. For example, Sigma-Aldrich Chemicals have provided chemicals, free of charge, and have pledged to continue this arrangement. Naturally, this has made the success of the USSL more secure. Their UK website has a link to the USSL.

Currently, the day to day running of the laboratory is carried out by a Schools Liaison Coordinator, employed on a fixed term contract by the Department of Chemistry and by the department's School Teacher Fellow (1 day per week). A small amount of technical support is provided by a chemistry technician from the undergraduate teaching labs. Administrative and secretarial duties are carried out by the School Liaison Coordinator.

A range of activities are available in the USSL but the most regularly requested and popular activity has been the synthesis of paracetamol. The two stage synthesis has fitted perfectly into a day in the USSL. The students' samples of paracetamol have then been analysed by ^{1}H NMR 'while they wait'. This 'hands on' approach, using machines that students will not see in school has been an extremely popular end to the session. Schools can book longer 'Spectroscopy Afternoons' where they get to analyse unknown compounds by mass spectrometry, IR spectroscopy and ^{1}H NMR spectroscopy. These sessions, additional to the USSL sessions, are offered on Wednesday afternoons and become fully booked for most of the year.

No charges are made for use of the USSL or the Spectroscopy courses, although this policy is one that is under continued review. Nor are charges made for our outreach activities such as visits to primary schools. In the past twelve months, the Department of Chemistry has engaged with almost 1000 Y5 and Y6 students in their schools.

To date, around 3000 school and college students have used the USSL. The age range has been Y5 through to Y13 although the vast majority of these have been KS5 students. The schools have attended from as far afield as Manchester to Grimsby and Huddersfield to north Birmingham.

Unsolicited verbal and written comments from students and staff that have used the lab have been universally positive. There have been several examples of the students' experiences having had a decisive effect on their choosing chemistry at undergraduate level. The impact on the university has been positive for several reasons. Most directly, the university has benefitted from students choosing to study at the University of Sheffield. Less quantifiable is the effect that the work has had on the way in which the community views the university. It has been the intention that the local community views the university as a partner that can augment the experiences of school and college students.

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The positive impact on chemistry teachers visiting the USSL should also be considered. Many teachers have commented upon their enjoyment of the visit and how a day in the university has refired their own love of chemistry.

Other Schools' Laboratories

Other schools chemistry laboratories up and running in British universities include those at Liverpool and Newcastle. One lab is thought to be in the planning stage at Imperial College London.

At Newcastle a £250,000 refurbishment converted a derelict undergraduate chemistry laboratory into a new outreach laboratory equipped to university standard. An adjacent room offers ICT facilities. The costs were met as a result of a major fund-raising campaign in 2010. Newcastle has its own School Teacher Fellow in charge of the facilities as an 'outreach officer' [19].

At Liverpool 'The SchoolsLab', opened during Science Week 2007 and can host groups of 15 visiting students. As with Sheffield and Newcastle the accommodation is an existing small laboratory. There is a requirement for a 'modest contribution' towards running costs for most events and sessions, intended for use by students from 10 to 18 years of age, run throughout the academic year. This lab, along with the others highlighted here is also used in teacher training. The SchoolsLab is sponsored by the Ogden Trust and the Engineering and Physical Sciences Research Council (EPSRC). For information on Liverpool's programmes please see <www.liv.ac.uk/chemistry/SchoolsLab/index.html>.

What is the impact of using such facilities?
The Royal Society of Chemistry (RSC) also commissioned 2 reports[20-22] as part of the evaluation of the Chemistry For Our Future (CFOF) on the use of the two laboratories at Bristol and Sheffield as 'Strand 4: Better Use of Laboratories' Bristol has also had the use of its facilities in delivering outreach activities the subject of research projects by two Masters level students[14,15,23].

The RSC used short *pro forma* to gather feedback from young people and teachers attending three student-focused careers events in early 2009. The information gathered was analysed by the National Foundation for Educational Research (NFER) as part of the RSC's evaluation of the CFOF extension phase[21]. The analysis showed that visits to university laboratories their contact with staff, undergraduate and postgraduate students:

- raised student's aspirations about going to university;
- improved student's attitudes towards and images of chemistry;
- improved student's perceptions of chemistry and view it as 'practical, fun, interesting and exciting;
- students gained practical skills and opportunities to develop more detailed and complex experiments at the university sessions thus enhancing their chemistry knowledge and skills and
- improved chemistry uptake and achievement at GCSE (at 16 years of age) and in pre-university chemistry courses.

The authors are not aware of any intended follow-up study to monitor long term impact of this cohort.

The longer-term and wider impacts for pupils include impressions and perceptions of chemistry and Higher Education (HE) with their use of university lab facilities having an impact positively on the general uptake of HE, recruitment to the host university and university chemistry[17]. The latter is important because young people engaged are able to make more informed choices about chemistry degrees having visited a chemistry department. This fact has been shown by the work of Shaw *et al*[3], where the impact on choice of degree was significant following attendance at a series of summer schools.

About four-fifths of the students felt that the work of scientist is good for them, whereas about three quarters of the students thought that it would be interesting to earn a living in a scientific community.

More specific research into outreach impact was carried out by researchers at Bristol. Tuah[15] questioned 49 students from 3 schools of 14-16 year old students about their various attitudes towards science after their involvement with the lecture demonstration on 'A Pollutant's Tale' and a polymer science workshop held in the undergraduate teaching laboratories[3]. Overall, Shaw[23] found that the Bristol ChemLabS project was having a lasting impact because of the congruence between what was being provided for the students and what they already knew. The language, scientific terminology and scientific levels were all well matched to the incoming school students, an important result of the impact of using a School Teacher Fellow.

Significantly, a Percentage Positive Response (PPR) of more than 90% indicates students' positive views that a job related to science or career of or related to science would be interesting. About four-fifths of the students felt that the work of scientist is good for them, whereas about three quarters of the students thought that it would be interesting to earn a living in a scientific community. Four-fifths of the students also thought that they would enjoy being scientists, but only about three-fifths of the respondents thought that they would like to work as scientists[23].

Overall, a PPR of 82.6% indicates the students' positive views about a career in science whereas only 15% were non-committal and 2.4% disagreed with the idea that a career in science would be interesting. In the same study the majority of the teachers attending responded that the outreach activity was a very good way of promoting the learning of the science concepts among their students. The practical workshop was highly valued by the majority of the teachers, stating that their students were given the opportunities to perform experiments that are inaccessible in school.

Shaw[23] measured the impacts of several outreach activities over time. A few of her results are reported here.

(a) Data was obtained on applicants to Bristol's School of Chemistry since 2005/2006. This was combined with information on schools engaged with Bristol ChemLabS outreach, to identify applicants that came from engaged schools[17].

- Analysis at school level showed that in the period 2006-2008, engaged schools had a significantly higher average number of applicants than non-engaged schools.
- Students from engaged schools were significantly less likely to decline a place if offered one.

(b) Identical questionnaires were given to attendees of the Chemistry Experience Camp in 2008 and 2009, and responses were compared over time. This short residential course was open to students considering applying for chemistry at any university in the UK. All students in 2008 and almost all in 2009 planned to apply for a chemistry related degree (there were some students considering medicine), and around two thirds in both years said they planned to apply to Bristol.

(c) Secondary aged children attending a chemistry day for University of Bristol employee's children were given a short questionnaire on their enjoyment of the day after attendance[5]. Parents were then sent a follow up questionnaire a number of months after the event, to assess their perception of potential effects of the experience on their offspring.

- Parents' reasons for volunteering their children to attend tended to relate to helping them with their current studies, because the child was interested in chemistry or because they wanted to encourage some interest in chemistry, and to give them experience of university and science in a university.
- Parents' observations of the immediate benefits of the day to their children tended to be related to the following factors: enjoyment of the day, enthusiasm and interest in chemistry, insight into the subject and university, and increased learning of skills and knowledge.
- Parents' observations of the long term benefits of the day to their children tended to be related to the following factors: increased interest in chemistry/studying chemistry helped or will help with decisions about future study, increased confidence/ attitudes. Around a quarter of parents felt unsure about what long-term benefits might be, or that it was too early to tell.

Bristol ChemLabS trains and uses postgraduate students to demonstrate and assist with lab sessions, essential for the numbers present per session ...

Summary and Conclusions

There are clear positive impacts of both approaches and several common themes. First, both approaches used a School Teacher Fellow to run and direct the laboratory sessions and this was the single most important reason for the success of both projects. Second, both approaches worked from a logistical and administrative point of view and science departments could easily adopt whichever one was most appropriate to them. One does not need to build a dedicated school laboratory, but can use the existing one. Any fears about wear and tear and misuse just does not happen, provided that good communication is established with schools beforehand (an STF would do this as a matter of course). The disadvantage is that the times the laboratory maybe used is restricted in term time, but the rest of the year it can be utilised most effectively. If it is more appropriate to build a dedicated laboratory (with the cost implication) then there is a facility that can be used all year round and there is no fear of disruption to the undergraduate facilities. It can also be adapted more easily for use by other groups such as primary aged students or those with disabilities and this would be a distinct advantage. In terms of the range of experiments that can be covered, both approaches are equal in their scope.

Third, the impact on both sets of providers in having a regular throughput of schools is an important one, providing constant feedback and updating from secondary school teachers. For example this may provide deeper insight into examination board emphasis on particular experiments or terminology used with practical or lecture components of such visits. Whilst this is less important in the curriculum broadening visits it is very important in events designed to support the curriculum.

The issue of sustainability of the two approaches is an important one. Funding a laboratory through departmental or University funds is possible up to a point. However, it is impossible to fund the throughput at Bristol ChemLabS from departmental or university funds. Therefore, as the project grows this problem must be tackled and the only option is to charge for activities or find a sponsor or both. At the USSL a Schools Liaison Coordinator is funded for 4 days per week through money obtained from variety of events such as delivery of the RSC's Chemistry for Non-Specialists and not centrally by the department. Here also the long-term funding of this post is uncertain.

Bristol ChemLabS trains and uses postgraduate students to demonstrate and assist with lab sessions, essential for the numbers present per session whereas the USSL is run by one person, either the STF or the Schools Liaison Coordinator. If larger numbers are accommodated per session, more staff are needed to demonstrate and the employment of postgraduates may not be possible (low numbers or unwillingness to allow them to engage in this activity). This is then an important consideration and a potential drawback to the Bristol ChemLabS approach being widely applicable.

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The issue of sustainability... is an important one. Funding a laboratory through departmental or university funds is possible up to a point.

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