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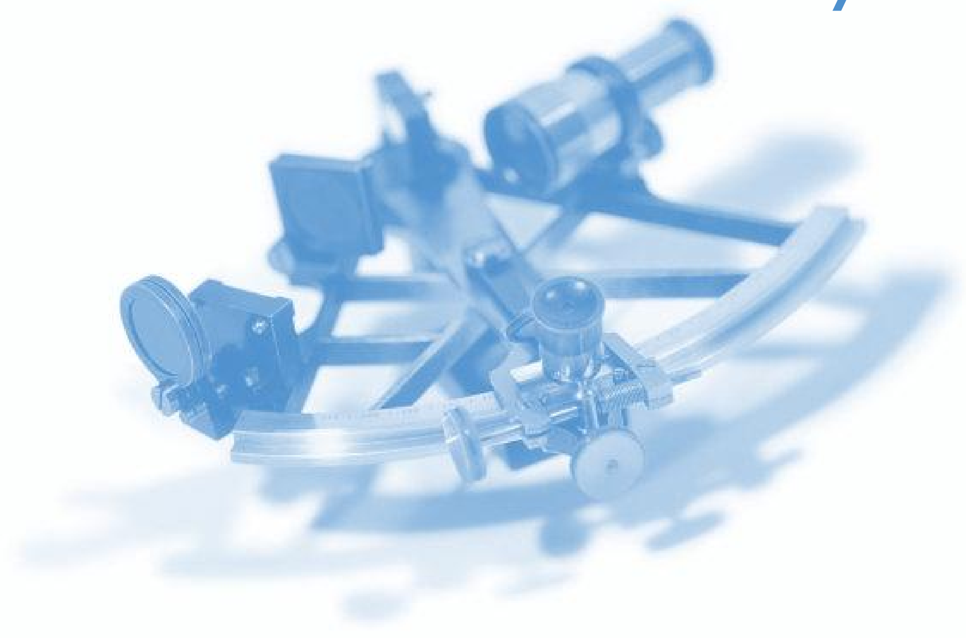
New Directions

in the Teaching of Physical Sciences



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

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

An editorial board reviews all submissions.

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Editorial

New Directions is the Physical Sciences Centre's publication focusing on new developments by practitioners in the field of learning and teaching.

In this issue we feature articles from a range of contributors covering a wide range of interests, from the inclusion of forensics skills teaching in law degrees, through concept mapping and context based learning to the Undergraduate Ambassador Scheme.

The popular topic of outreach continues from the previous three issues of *New Directions* with an article on a large scale outreach activity across the schools of Jersey and another looking at the use of technology to increase engagement in outreach.

There are also contributions on another popular area, that of the use of technology in learning and teaching. Articles include those on the use of assistive technology, electronic marking of assignments, online assessment and the use of electronic voting systems.

We hope you will enjoy this look at some of the current activities of physical sciences practitioners and will find something to inspire you in your own practice.

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The traditional law degree dilates this educational lacuna by failing to introduce law students to the most basic of scientific concepts, or provide even a rudimentary grounding in the work of forensic scientists.

When science doesn't meet the law: addressing the absence of forensic skills in law degrees

Abstract
This short article outlines the development of an educational package to bring forensic science into the law curriculum. It details a current project at Leeds University, in collaboration with forensic science educators from Staffordshire University.

Scientific Illiteracy and the Legal Profession

The perceived 'scientific illiteracy' among the general public can be seen to extend its reach into the legal profession. This is perhaps not surprising when looking at the scientific education of law students, most of whom have not studied any scientific discipline post-16. Of the 214 students given an unconditional offer to study the LLB (Bachelor of Laws) at Leeds commencing in 2007, just 39 (18.3%) had at least one science A-level (biology, chemistry, physics or human biology)[1]. The traditional law degree dilates this educational lacuna by failing to introduce law students to the most basic of scientific concepts, or provide even a rudimentary grounding in the work of forensic scientists. A survey of law schools in England and Wales finds that of the 76 LLB programmes on offer, just four[2] advertise any 'forensic' modules available during their 3 year programme (some forensic modules may possibly be available as electives within other departments). So not only do a minority of students enter onto the law degree programme with *any* scientific background, very few will leave having come into contact with 'science' during their degree. This is then compounded by the Legal Practice Certificate which qualifies an individual to practise law (or Bar Vocational Course for aspiring barristers); this certificate incorporates *no* science.

Such omissions should be of concern when the legal system has recourse to science with increasing frequency, particularly within the realms of criminal law. Upon qualification, all lawyers are quickly required to understand and manipulate information from scientists and other experts - the onus currently placed upon the expert to make their evidence understood by the non-expert. The House of Commons Science and Technology Select Committee in 2005 stated that: 'Forensic science is now central to the detection and deterrence of crime, conviction of the guilty and exculpation of the innocent. Moreover, the significance of forensic science to the criminal justice system can be expected to intensify in years to come,'[3] and yet were forced to report that: 'it is of great concern that there is currently no mandatory training for lawyers in this area.'[4]

This shortfall in legal training can be contrasted with the situation in forensic science departments, where there is emphasis placed upon students not only learning the science, but also the legal context and the operation of the law. A forensic graduate without a grounding in the law would be rightly considered lacking in training. Forensic science students learn about courtroom etiquette and present their scientific findings as an expert witness having investigated a crime scene scenario. They give evidence-in-chief and are robustly cross-examined by science lecturers who themselves have acted as experts at court. The corollary of this for some parity in law education should be that law students **would** attend a crime scene scenario and then subsequently be examined on their science-based findings from *that* scenario.

The use of forensic science in the criminal justice system involves long chains of activity stretching from preparatory work *before* a crime is committed, for example the manufacture and supply of equipment for collecting forensic samples, through to the presentation of evidence at court[5]. This complex pattern demands a fundamental level of understanding of forensic activity, in order to identify issues that may have a significant impact upon the outcome of a legal enquiry. All legal practitioners should take a court-centric view of the forensic science and be able to reflect upon evidential aspects. This also then requires a thorough understanding of what the courts require from forensic science and is reported by the recently appointed UK Forensic Regulator as a perspective "that has never been comprehensively examined"[6].

The 'problems' with forensic science and mistakes made by experts in court are rehearsed in the media on an increasingly regular basis. Normally absent from such criticisms or wider critiques of the legal system is any examination of why it was that no lawyer was able to spot a potential issue or why no legal professional had drawn attention to errors before damage was done. Yet, criminal lawyers can avoid any scientific training throughout their education and professional development and this appears the norm. This should stimulate a wider debate about forensic skills within law degrees and legal education being 'fit for purpose'.

Introducing forensic science to law students

In an attempt to address the lack of basic forensic science information within law degrees, this project, funded by the White Rose Centre for Teaching and Learning Excellence in Enterprise at Leeds, is developing an existing module within the Leeds law curriculum – *Forensic Process and the Law*.

Law and forensic academics first met during a conference organised by the Forensic Institute Research Network

Figure 1: Chain of custody and contamination issues are paramount in an effective investigation.

Figure 2: Issues of risk assessment and health and safety at crime scenes are equally important in the legal framework of an investigation.

(FIRN), which is an international collaboration of universities created in 2004. FIRN is a cooperative with the aim to, *"improve the quality and quantity of forensic science research and teaching"* and at a meeting in 2007 the idea for such a project was suggested.

Subsequently, working in conjunction with experts in forensic science education and web-design specialists, the project aims to develop a series of innovative web-based exercises and assessment for law students The intended outcome is to have designed a resource that law students will work through as a realistic forensic-case study and present their findings in both written and oral form as part of their assessment. They will need to work through the forensic processes that would occur in the actual investigation of a criminal case.

The Crime Scene House on the Staffordshire University campus was utilised, as well as 'actors' and a professional forensic photographer, to enact and record a crime scene, for use in the simulated exercise. This exercise resulted in a 'bank' of nearly 1000 high resolution photographs which can be used by the project leaders for future developments. This large number of images allow for flexibility in the presentation of the many facets of evidence and the overall crime scene.

...criminal lawyers can avoid any scientific training throughout their education and professional development and this appears the norm. This should stimulate a wider debate about forensic skills within law degrees and legal education being 'fit for purpose'.

The undergraduate Forensic Process and the Law module (with a postgraduate variant) is a 10 credit module with a cohort of 60 students. The module descriptor states that on completion of this module, students will acquire the following subject specific skills:

- comprehend and amass data about forensic process and the law
- make well-grounded, well-structured and well-referenced oral and written presentations about the subject
- analyse and criticise the data using the policy goals and also normative standards such as human rights
- plan, develop and produce research of an appropriate level, from the information supplied and recovered.

The project is developing this module from a purely theoretical, lecture-based module, to incorporate in addition a more practical problem-solving approach where the students apply themselves to a 'real' crime. The work, based upon realistic situations, will clearly illustrate where law meets forensic science. This practical approach is facilitated by a web-based assessment, where students work through a series of problems, based upon realistic criminal cases. These will be done individually by the students, and then progress into seminars based discussions. This web-based learning will enable the development of:

- critical thinking and analysis: Problem solving; creative/ lateral thinking; constructing logical, coherent, cogent arguments; critical reading and manipulation of complex materials
- fact finding: utilising variety of resources; application of law to the facts; use of different disciplines outside of law, use of information technology to retrieve resources; understanding and working with both scientific and legal rules and procedure.

The exercises will also demand of the students, initiative and problem-solving skills as well as stimulating creativity and team-work.

Participants will be required to take on the decision making roles of the Forensic Scientist/ police investigator/ legal representatives (defence/ prosecutor) and ultimately, judge. They can compare their outcome with the real outcome of the case. They should then develop an awareness of the decision making and constraints that govern the use of the science within the criminal justice system. It is expected as an outcome of this work that law students will develop the following:

- an appreciation of the role of a forensic scientist within a criminal investigation
- an understanding of how the use of science is prioritised within an investigation
- an awareness of how the application and use of science is justified within a criminal investigation
- an understanding of the different roles/ agencies involved in a complex criminal investigation and how these intersect
- an appreciation of how scientific evidence fits within a prosecution or defence case and how decisions made during investigations impact upon evidence which may be presented at trial.

This innovative development should begin to tackle the scientific shortfall in the training of law students. At some future point, a reflective analysis of the impact of such forensic -training should be undertaken to determine the usefulness of this initiative and this indeed could be fed back to the UK forensic and legal regulatory bodies to consider rolling out such a programme of study nationwide. This is clearly only a start for the undergraduate training process where hopefully forensic science will meet the law in a complimentary fashion rather than simply head-on in the courts.

References/Notes

1. A further 54 had maths or psychology A-level.
2. University of the West of England; Huddersfield; Leeds and Sussex.
3. House of Commons Select Committee on Science and Technology, Forensic Science on Trial (2005) (HC96-1) p.8.
4. ibid. p.79.
5. Forensic Science Regulator Business Plan 2008-9, p.9
6. ibid, p.10.

At some future point, a reflective analysis of the impact of such forensic-training should be undertaken to determine the usefulness of this initiative and this indeed could be fed back to the UK forensic and legal regulatory bodies to consider rolling out such a programme of study nationwide.

The Undergraduate Ambassador Scheme implemented at St Andrews

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Abstract

The Undergraduate Ambassador Scheme (UAS) is now a well-established project across many UK Universities[1,2]. In this scheme undergraduate students in science, engineering, and mathematics go into local schools to learn from and assist teachers as part of credit-bearing studies for their degree. UAS has a central office that can provide significant help to universities to set up and run such a scheme, though each university is responsible for its own implementation.

This article aims to give an overview of the Undergraduate Ambassador Scheme, its implementation in physics at St Andrews in session 2007-8, and the issues and benefits that we have observed in this first year of operation.

Many universities have provided opportunities for their students and local schools by encouraging students to take part in activities in local schools on a voluntary basis. These schemes can prove highly successful. A difference between these schemes and the similar Undergraduate Ambassadors Scheme (UAS) discussed here is that in the UAS the students' work counts towards academic credit in their degree programme. This can make such placements more attractive to students both through the provision of credit and through the recognition by the university that this is a valuable educational experience. The learning experience can be further enhanced by the necessary discussions with university staff and students, and by the reflective work that the students are required to undertake as part of the module. Bringing the placement into a credit bearing module also provides greater incentive for students to be fully committed to the school placements, and may also provide greater incentive for university and school staff to ensure that the students' placements are appropriately supported.

In 2007-8 the University of St Andrews ran the Undergraduate Ambassador Scheme for the first time, rolling out the scheme across its Schools of Physics & Astronomy, Chemistry, Biology, Mathematics and Statistics, and Geography & Geoscience. We are told that ours is now the largest implementation of the UAS in Scotland[3]. We acknowledge that other physics departments in the UK have been successfully running this scheme for some time, including the University of Surrey[4] as one of the first set in 2002-3, with support from the Physical Sciences Centre. There are now some 110 departments in 42 universities running the scheme.

The UAS was set up in 2001 by author and broadcaster Simon Singh. Our University's involvement in the project became more focused after discussions with Simon when he gave a public lecture in St Andrews. The aims of the UAS fitted with our wishes, which were to:

- provide our students with the opportunity to improve science communication skills,
- provide our students with an opportunity to gain further employability skills,
- allow our students to experience something of the work of school teachers,
- strengthen our links with local schools, including in the widening participation agenda,
- assist science teaching in local schools,
- encourage the next generation of young scientists.

We note that many of the aims of the UAS fit with aspects of the honours degree benchmark statement for physics[5] and the Institute of Physics criteria for accredited degrees[6]. Our discussions showed that the UAS organisation could provide a great deal of no-cost input in terms of templates for the organisation of such a module, relevant paperwork for use in the module, evaluation reports on the scheme, and even some financial support.

We note that many of the aims of the UAS fit with aspects of the honours degree benchmark statement for physics and the Institute of Physics criteria for accredited degrees.

Dr Alyson Tobin of the School of Biology took the lead in the organisation of the new module, in collaboration with academic staff in each of the participating departments. In due course the University's committees gave approval to a new interdisciplinary module ID4001 Communicating and Teaching Science. In St Andrews this module runs in the first semester and is worth 15 credits of the standard student load of 120 credits a year. The module handbook, which is available online[7], was based on the excellent material on the UAS website[1].

Academic staff and Schools-liaison staff worked with local schools to find placements for the students. Late in the academic session we invited applications for a place on the module from students in their final year (final plus penultimate year for MPhys students). Interviews were held to select the students to participate in the module, which included for physics students a conceptual query on rocket thrust from a "pretend" 14 year old. The selection procedure is unusual in our system, but then so is this module. The schools and the University needed to be sure that those going into schools are committed to the activity and bringing relevant expertise to the placement. It is usual for our students to be able to change their choice of module for a short time at the start of the academic session, but this cannot be the case for this module, given the external commitment. While the selection committee was aware of the academic qualifications of the applicants, this was not the primary factor.

The academic staff in all subjects noted how quickly most students' confidence grew through the teaching and communication experiences in the module.

Over the summer, successful applicants went through the formal process to ensure that they had not been determined as being unsuitable for working with children, and students and teachers were linked together. In the first year of operation 32 students were placed in 11 Schools in Fife and the former Tayside. Seven of these were physics students.

Students attended a workshop in orientation week to help prepare them for the school placements. This included an external speaker from Her Majesty's Inspectorate of Schools, who has been involved in many of the recent curriculum developments. We are fortunate to have a number of university staff members who are former school teachers, and they also contributed to the induction session, along with a student who had taken part in voluntary work in schools. As well as hearing about current work in schools, our students were actively engaged in various "what if?" scenarios.

The students were required to liaise with their link school teachers to determine what times of the week would best suit their own timetable and that of their school. They then attended the school for the equivalent of a morning a week for the duration of our semester. Email seemed to make this arrangement work more easily than might have been the case in the past. The students organised their own visits to the schools, with the University providing travel expenses for those with a longer journey. Our students reported in most cases being warmly welcomed into their schools, with their anxiousness being eased by the care that the teachers took in integrating them into the school communities.

The intention was that the first visits would be primarily observing the teacher at work with various classes, and then as the semester progressed the students would take a more active role with, for example, helping with practical classes and in one-to-one support with pupil questions. In some cases a student borrowed equipment from our department to illustrate the work being done in school, for example by taking in an endoscope to a lesson on total internal reflection and light guides. The goal was to build on these experiences with a "special project" towards the end of the semester, where the student would take the lead on part or all of a lesson, albeit under the direct supervision of the host teacher. Special projects in physics included bringing one group to the University to undertake relevant teaching-lab experiments, developing a statistics lesson based on sampling from packets of sweets, and developing and presenting a "fun" educational quiz on electronics.

The students were required to reflect on their experience after each school visit and compiled a log book that identified the successful aspects of the visit and aspects that needed improvement. They also worked closely with the teacher in preparing for the next visit through revision and writing any necessary teaching plans. The main "teaching" of the students was done through discussion between the student and teacher, but support was also provided in the University through small group tutorial sessions with a subject tutor. A great deal of experiential learning was also taking place, both in the professional skills and in a deeper understanding of the physics topics involved. The academic staff in all subjects noted how quickly most students' confidence grew through the teaching and communication experiences in the module.

Assessment of the students' achievements was done in four ways:
25% on the school teacher's view of the student's work
25% on the content of the student's log book
25% on the student's end-of-module reflective analysis and report
25% on an oral presentation on a chosen aspect of the student's work.

We evaluated the module via anonymous questionnaires with the students, input from teachers, and our own observations.

Three of the physics students offered comments that they were willing to have published:

Student A: - “*This module has given me invaluable experience in science communication. It not only gave me an insight into teaching various age groups but also how to go about communicating ideas to them in a relevant way. As I was mostly teaching just one class I was able to build up a relationship with the pupils in said class and I hope that I may have inspired some of them to carry on studying physics at higher levels and made them realise that physics isn't boring but can also be extremely useful and fun. I think that this is an excellent scheme both for students like myself, for the experience it gives us in teaching, communication and interpersonal skills; and for the pupils in the schools, as it gave them someone to relate to that wasn't a teacher and was nearer their age so that they could find out what university was like*.”

Student B: - “*I thought overall the module was very well put together, containing lots of aspects which will be useful as career skills. It offered enough classroom time to get a feel for whether teaching would interest me full time, without getting too involved at the school, which was a good thing due to time pressures with a subject such as physics. The module ensured the development of transferable skills with much of the assessment based around self analysis of a range of skills from communication to planning and time management.*

In some respects I felt the self analysis expected of us was slightly excessive, however, it did highlight the large range of skills one can benefit from by taking ID4001. I liked being able to work directly with the teacher in planning the level of involvement that I could afford and be comfortable with. In all I thought the module was enjoyable, interesting and rewarding, and would recommend it to anyone, especially those who might consider teaching at some stage in their career."

Student C: - “*The ID4001 module offered a valuable insight into the education system that I believe is hidden from the general public. For me, as a science undergraduate, I relished the opportunity to play my part in rectifying the shortage of applicants to higher education in the subject.*

The managerial skills that I have developed and attribute to participating in the module I believe will be important for my future career. The experience of organising and augmenting a lesson, in addition to dealing with all the unexpected issues that arise from a class of high school students as they happen, will be priceless. I have learnt the importance of clear and thorough communication, and have gained an understanding of the skill that is required in the use of language style and visual aids to avoid misunderstanding in an audience. Accordingly, I have developed even more respect for those in the difficult profession that is teaching.

Overall, I hope that the students and teachers I worked with gained as much from my participation in the classroom as I did. In addition, through my enthusiasm and by utilising the facilities that St Andrews School of Physics and Astronomy has at its disposal, I hope that students experienced a modern and exciting side of physics that would otherwise have been beyond the constraints of the classroom.”

We felt that the module ran remarkably well, which is testament to the support provided by the UAS office, and the input from students and school teachers. For the coming session we are reducing the emphasis on the daily log books, and some of the summative assessment procedures will be moved from the end of the module to part way through. The teachers’ assessment stays at 25%, and we are introducing a “proposal” document for the special project at 10%. The oral presentation will be on the Special Project and be worth 30%, and the balance will be on the written report on the placement, which will use information from the reflective log sheets.

At the request of the teachers we will try to get students into the schools a little earlier, as in some cases last session students had only just got into the schools before the October break. The tutorials that I run will be more structured, and I will endeavour to increase the amount of feedback through formative assessment.

One senior teacher commented “The scheme seems to have been well received here as well; I think it does well because it has a clear focus and end result as opposed to an ad hoc arrangement.”

We now have other departments within the University seeking to join the scheme, and the total number of students being placed in the coming session has risen to 42, which says positive things about the way that this initiative has been received by schools, staff and students.

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Using assistive technology in the classroom

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Abstract
The use of technology is now ubiquitous in Higher Education but its use or application to promote student inclusivity is not always well recognised. The use of existing software or hardware with a little more thought can often bring serendipitous benefits for a range of students. The JISC funded service, TechDis (www.techdis.ac.uk) offer periodic funding under its HEAT (Higher Education Assistive Technologies) scheme to promote the use of technology for inclusive teaching. TechDis says that 'The aim of this scheme is to provide staff working in HE... with technology ... with which to develop or uncover an aspect of good inclusive practice. This may be specific to the teaching of a particular discipline, supporting a specific role area, or may have more generic applicability across the sector'. This article will discuss how TechDis funding was used with students to assess its potential benefits for inclusive teaching.

Introduction
Perhaps without realising it, we all use technology that will have an impact on the way students are able to learn. Although recent disability legislation aims to reduce risks to students with recognised disabilities, some of our practices are not always so obviously inclusive. For example, some dyslexic students may have difficulty reading black text on a white background, so making copies available on different coloured paper can help. In the lecture theatre we often use presentations but how visible are they to students and if we try to engage students by asking them questions, how many break out into a cold sweat? As an example of using assistive technology (or perhaps more accurately, using technology in a more assistive way) the author reports on the use of technology for more inclusive teaching. The technology used was a Gyration wireless mouse and compact keyboard to support student interaction during a scheduled class.

Perhaps without realising it, we all use technology that will have an impact on the way students are able to learn.

TechDis project bid
The TechDis project was aimed at using the Gyration wireless technology as an example of how technology can support student interaction and feedback to encourage a more inclusive participation in the lecture theatre. It was intended that this would be a good example of how assistive technology can be used to encourage greater participation of students during lectures, especially from students who are too scared to interact in such public situations or who may have difficulty due to other reasons, perhaps through disability.

Overview of equipment
The Gyration wireless gyroscopic optical mouse and compact keyboard is produced by the company of the same name. It has an 'innovative mouse with gyroscopic motion-sensing technology for in air navigation' and 'up to 30'/9m range thanks to 2.4GHz RF (radio frequency) technology (Fig. 1).

The product website lists the following features of the product:

- Ergonomic mouse design for comfortable desktop and in-air use
- Compact cordless keyboard with whisper quiet keys for maximum productivity and minimum clutter
- Gyroscopic motion-sensing technology for in-air use provides navigation with no delay while the precise optical sensor is perfect for desktop use
- Three distinct programmable mouse buttons
- 2.4 GHz RF receiver with up to 30'/9m range with no line-of-sight limitations
- NiMH rechargeable battery with desktop charging cradle
- GyroTools™ Media Control software for Microsoft Windows® (*Software installation required).

Figure 1: Gyration wireless gyroscopic optical mouse & compact keyboard

Intended outcomes of project
The first aim of the project was to trial the Gyration keyboard and mouse and to assess whether the equipment functioned appropriately according to the product claims. The second aim was to evaluate whether the integration of the equipment into a teaching environment might enhance the learning process by encouraging greater student participation. The third major aim was to attempt to evaluate the potential of the equipment for use as assistive technology. This could involve the support of students who may be shy and have difficulty interacting during class or have difficulty interacting for other reasons such as physical disabilities. Therefore, the three major outcomes of this project were:

1. Assess the functionality of the Gyration equipment
2. Trial the use of the Gyration equipment in an active teaching environment
3. Assess the potential of the equipment as assistive technology.

Overview of teaching activity
The Gyration wireless equipment has the potential for students to participate in a class or lecture room setting in a more interactive manner. An old tried and tested method for engaging students in the 'classroom' is to ask them to come up to the (chalk/white) board and ask them to write answers or responses for the rest of the class to view. There is, however, a double edged outcome to this.

Involving students gives them the opportunity to address fellow classmates and experience giving a 'presentation' - which is a valuable interpersonal skill. A downside however, is that some students find this prospect daunting and in a large room of students there may be limited time to engage more than a handful of students for logistical reasons (time to come to the front of the class etc). Given these constraints the intention for the teaching activity was for the tutor to move around the room passing the equipment to different students during the session so that they could offer interactive feedback and input to the activities.

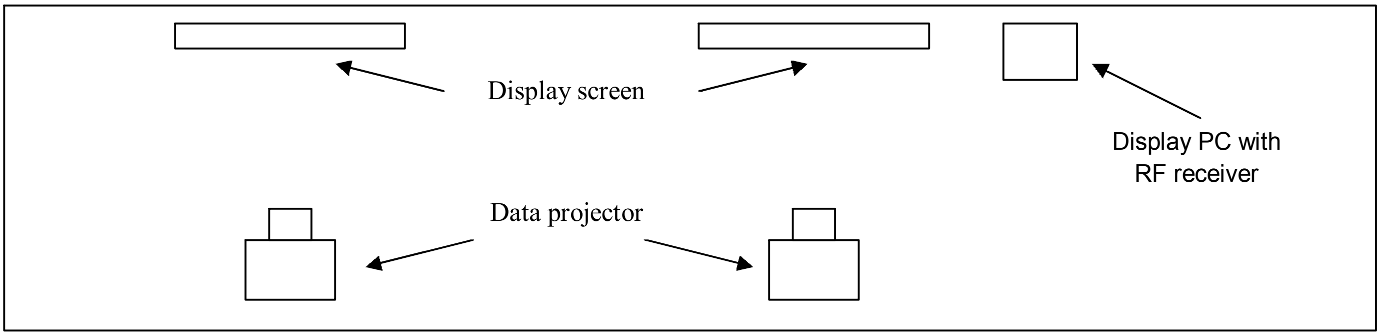

Figure 2: Schematic layout of room (approximate set up and not to scale)

The equipment was trialled during two IT classes for first year students, each with about seventy students. The tutor was able to move around the class during the demonstration parts of the session, taking questions and providing more timely and targeted feedback using the wireless equipment. This was in contrast to the usual static style where the tutor is usually stuck at the front having to demonstrate everything on the display PC connected to the data projector. This potentially allowed for more interactive demonstrations and questioning from students who might otherwise have been afraid to ask a question in front of the whole group. With the tutor moving around the class students may be more inclined to ask questions since they were near the tutor instead of having to shout the question out to the whole class. In addition to the demonstrations the students were given an extensive exercise to undertake during class where the intention was for them to demonstrate their work as the activity progressed.

Observations from study
The Gyration wireless keyboard and mouse was used in an IT teaching room that is rectangular in shape and approximately 30 metres in length. It has one display PC and two data projectors, as shown in Fig 2.

During a typical class given in a more formal presentation style from the front, only a few students would normally ask questions. In this trial, far more students asked questions when presented with the equipment.

Equipment functionality
Given the fact that the RF (radio frequency) receiver was a USB device connected to the display PC, meant that the signal did not reach the far left of the room for the equipment to operate all the time. The manufacturer suggests the product has a range of about 9 metres so its potential is limited by the size of the room. The equipment may work better in a standard (tiered) lecture theatre but the opportunity to pass the equipment around may be more restricted given the usual seating arrangements in a lecture theatre; ie it is not possible to move in and around rows of seats. However, given the stated specifications of the equipment, the Gyration product worked well.

More students asking questions
Whilst this was only one trial with two classes, this course has been taught by the author for several years. This means that it is possible to make the qualitative observation that by using the equipment and moving amongst the students, rather than presenting from the front, students seemed far more comfortable asking questions than usual. During a typical class given in a more formal presentation style from the front, only a few students would normally ask questions. In this trial, far more students asked questions when presented with the equipment.

Use of the equipment also enabled far more interactive demonstrations in response to direct queries. In a conventional session, perhaps only two or three students may be confident enough to ask a question whereas in this trial the author received over 20 questions from the students. The students were able to use the equipment to elucidate their query and these students provided further feedback by completing a brief anonymous survey at the end of the class. The results of the survey are discussed below.

Potential for assistive technology
One interesting observation made during the trial was the difficulty some students had using the display screen with the equipment. Students were given a task to complete and were allowed to work in groups of two or three. When they were asked to use the equipment they had to use the display PC connected to the data projector. This meant that the students had to look at the projector screen to view their work. The author soon realised that some students who wore glasses had difficulty seeing the screen in order to work on the computer. This could restrict the potential for such use for any student with visual impairments, even those with relatively 'minor' impairments who use glasses to correct their vision.

However, there was a positive response with this approach to student interaction. During the student exercise students were working in groups with no input from the rest of the class. This meant that when the author asked individual students from various groups to demonstrate parts of the exercise activities on the screen, there was less pressure since the whole class was not specifically looking. This meant that students felt more relaxed about getting involved and were more willing to attempt the activities than if they had to do it in front of the whole class. This use of the equipment clearly has potential for shy students to get involved in a class to help build their confidence.

Student survey findings
From the two classes in the trial, about 25 students had the opportunity to use the Gyration equipment. These students were asked to offer feedback on their use of the equipment by completing an anonymous survey at the end of the class. The author received 19 replies, which can be considered representative of the study. The students were asked if they found the technology easy to use and whether the equipment made the session more interactive. In each case 95% of respondents said that the equipment was easy to use and the session became more interactive. The short survey also asked if they would like to use the equipment again and 100% of respondents replied 'yes'.

As a potential for supporting disabled students as assistive technology, the students were asked if they felt the equipment may offer benefits for disabled students and 84% replied ‘yes’. A number of responses were given claiming that the technology would help students who were struggling with the topic during class and so would help their learning. The following are some quotes recorded:

“Using interactive technology really helps students to understand parts of the course that they don't, and helps the lecturer to pick up on students who are too shy to say they cannot complete a task. Interaction can also make the lectures more interesting and allows students to become used to new technology they would normally not be able to experience.”

“...to help pupils who are particularly struggling with a subject as it will allow help to be shown on a larger scale to help other pupils if they are also struggling.”

“The wireless technology allows the lecturer to be more interactive with the students.”

The short survey also asked if they would like to use the equipment again and 100% of respondents replied ‘yes’.

Discussion

Given the fact that this was a short trial with only two classes, a number of interesting issues were raised. Referring back to the three planned outcomes of the project, the first related to the functionality of the equipment. The signal strength of the RF receiver limits the potential for use in large rooms. The author also found that whilst the ‘in air’ functionality of the mouse was useful, it took a bit of practice to get used to. This involved dexterity skills to use the mouse accurately. When the students tried to use the equipment for the first time they found the mouse difficult to use in the air and so had to use it as a traditional mouse on the desk. The author feels that this may limit its use as assistive technology for students who have mobility issues. However, in terms of enabling a teaching session to become more interactive, it clearly works.

For the second aim to trial the equipment’s use in an active teaching environment, the results were very positive. The author was able to engage far more students than would normally be possible in a ‘traditional’ class. Students found the use of the equipment less threatening and so were more willing to engage and ask questions.

As potential for the Gyration product to provide good assistive technology in the class, the current trial did not manage to cover fully its potential. Students with mild visual impairments (wearing glasses) had difficulty using the equipment because they could not see the screen properly. However, this is not necessarily the fault of the equipment but more to do with the general set up of visual aids in the room. Students with other disabilities such as physical tremors may find the gyro mouse difficult to use but overall the author felt the equipment was a success when used to engage more students who might otherwise be too shy to interact in class.

Electronic marking of physics assignments using a Tablet PC

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Abstract
Producing and marking assignments electronically has advantages for both students and academic staff. However, marking and commenting on electronic assignments requires a simple and efficient method for annotating students' scripts. We report here on a pilot project that provided associate lecturers (ALs) for a Level 2 Open University physics course with Tablet PCs and appropriate software that enabled them to input handwritten annotation, including equations and diagrams, to files containing students' solutions to assignments. Surveys of the views of ALs indicated that this method of electronic marking is effective and acceptable to students and to a large majority of ALs. It could be used to streamline assignment handling and marking procedures in campus universities as well as in distance learning contexts.

Introduction
The majority of Open University courses include summative tutor marked assignments (TMAs), which are submitted by students at intervals during the presentation of a course. The TMAs are marked by associate lecturers (ALs, also known as tutors), who are based in different locations around the country and are each responsible for a group of about 25 students. The traditional method of producing and marking TMAs is paper based: a student writes their answers to the assignment questions on paper (or word-processes them and prints them out), they use the postal system to mail the assignment to their AL, who marks and comments on the assignment by annotating the student's script. The AL sends marked assignments to the Open University in Milton Keynes, where the marks are recorded in a database, a sample of scripts are copied so that each AL's marking can be monitored, and the scripts are then posted back to students. This system involves shuffling large quantities of paper around the country and there are delays, expense and inconvenience associated with the postal system, with the transcription of marks and with the copying of assignments for monitoring. Now that OU students and ALs are expected to have access to a computer and the internet, some of the delays, costs and inconvenience can be reduced by handling TMAs electronically.

The majority of Open University courses include summative tutor marked assignments (TMAs), which are submitted by students at intervals during the presentation of a course.

The OU has developed a system for handling electronic tutor marked assignments (eTMAs), and is encouraging course teams and students to use this system wherever possible. The eTMA system allows students to submit electronic files containing their assignments over the internet to a file handling system on a server in Milton Keynes. ALs download the eTMA files for their students from the server, mark and comment on the eTMAs offline, and then return the marked scripts over the internet to the server in Milton Keynes, where marks are automatically recorded in the appropriate database and a sample of scripts is made available for monitoring. Students can then download their marked assignment from the central server. This system has many advantages for students, ALs and the OU over the paper-based assignment system that relies on the post office for moving the assignments around the country.

One advantage is that the eTMA system in principle allows ALs to give more rapid feedback to students following the cut-off date for the assignment than does the paper-based system. Gibbs and Simpson[1] established a list of conditions under which assessment effectively supports learning. A key finding of this work was that it is essential that "feedback is timely in that it is received by students while it still matters to them and in time for them to pay attention to further learning or receive further assistance".

However, the benefits of rapid feedback could be more than offset if a longer time were required for ALs to mark eTMAs to the same standard as paper TMAs, so that the quality and quantity of feedback provided to students were reduced. Assignments for physics and astronomy courses generally involve large amounts of mathematical notation, equations and diagrams, and when marking eTMAs, ALs need to be able to insert equations and diagrams, and the time required to do this is generally the major issue. Keyboard and mouse based tools, such as equation editors and drawing programs, are much more time consuming than annotating a paper script with a pen. The pilot project described in this report was set up to investigate ways in which ALs could mark physics eTMAs easily, and could incorporate equations and diagrams just as they would if they were marking a paper assignment.

The project
In March 2006 the Physics Innovations Centre for Excellence in Teaching and Learning (πCETL) at the Open University agreed to fund a pilot project to investigate the use of Tablet PCs by ALs for marking assignments. All of the ALs who were tutoring a Level 2 physics course, S207 *The physical world*, were invited to participate in the project, and 19 of the 24 ALs agreed to take part. The participating ALs were provided with a Tablet PC (Toshiba Tecra M4), with appropriate software installed to enable them to add handwritten annotation to a student's eTMA file. The following year (2007) all ALs for the course participated in the electronic marking project. Students were informed about the benefits of using the eTMA system, but they had the options of submitting assignments electronically or on paper.

Marking procedures with the Tablet PC
ALs had a number of options for marking and commenting on eTMAs using the Tablet PC.

Ink annotation of a pdf file using PDF Annotator
We wanted to allow students to produce assignments using whatever application they found convenient, but wanted ALs to be able to use a single application for marking. We therefore recommended that ALs used pdf format for marking. The Tablet PCs were sent out with PDF Creator[2] installed, and this application creates a 'virtual printer' that can convert into pdf format any student file that can be opened and printed from the AL's Tablet PC. The AL simply opens a student's assignment file – which requires that an appropriate application is installed on the Tablet PC – selects Print and chooses PDF Creator as the printing device. 'Printing' the file then produces a pdf version of the file, rather than printing out on paper. PDF Creator allows the user to combine a number of different files into a single pdf file.

The AL then opens the pdf file from the PDF Annotator[3] application. With the computer in the tablet configuration, the pdf file can be annotated by writing on the screen with the tablet pen in exactly the same way that a paper assignment would be annotated with a conventional pen, but with the advantages that it is straightforward to:

- change pen colour and line width – so it's possible to colour code different types of comments;
- erase or correct comments;
- move or resize comments;
- save comments as macros that can then be inserted easily elsewhere in the same document or in other documents;
- insert blank pages for additional comments, or to append files (such as specimen answers).

When the AL has finished marking, they 'melt' the annotation so that it becomes a permanent part of the document, they save the file in pdf format and follow the standard procedures for returning the eTMA to the OU server. The student downloads the marked assignment from the server and opens the file using Adobe Reader. An example of a page from a marked assignment is shown in Figure 1.

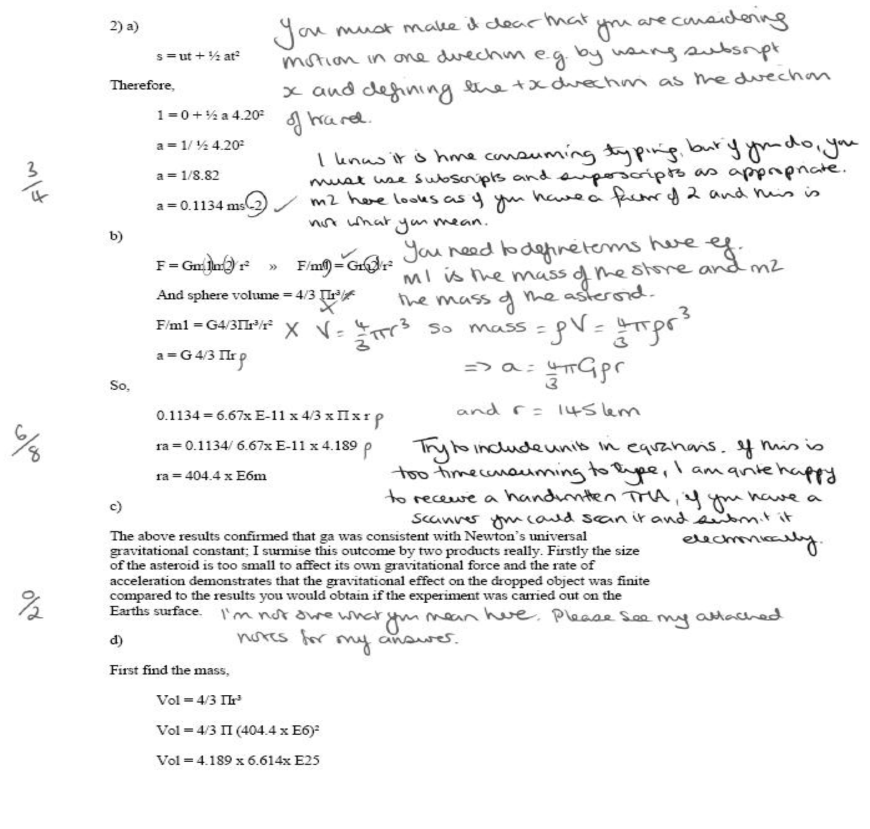
2) a)
s = ut + ½ at²
Therefore,
1 = 0 + ½ a 4.20²
a = 1/ ½ 4.20²
a = 1/8.82
a = 0.1134 ms-2
b)
F = Gm1m2/ r² » F/m1 = Gm2/r²
And sphere volume = 4/3 Πr³/r²
F/m1 = G4/3Πr³/r²
a = G 4/3 Πr ρ
So,
0.1134 = 6.67x E-11 x 4/3 x Π x r ρ
ra = 0.1134/ 6.67x E-11 x 4.189 ρ
ra = 404.4 x E6m
c)
The above results confirmed that ga was consistent with Newton's universal gravitational constant; I surmise this outcome by two products really. Firstly the size of the asteroid is too small to affect its own gravitational force and the rate of acceleration demonstrates that the gravitational effect on the dropped object was finite compared to the results you would obtain if the experiment was carried out on the Earths surface.
d)
First find the mass,
Vol = 4/3 Πr³
Vol = 4/3 Π (404.4 x E6)²
Vol = 4.189 x 6.614x E25

Figure 1: An example of a tutor's annotation on a page from an assignment. The tutor's comments would be much clearer to a student viewing a coloured image on their monitor.

PDF Annotator also allows simple text to be keyed into a text box. However, mixing keyboard entry and tablet pen entry is not particularly easy, since it involves switching back and forth between using the laptop configuration and using the tablet configuration. Switching between the two configurations of the screen takes about 15 seconds, which is not an unreasonable overhead, but the switchover is somewhat clumsy. An alternative procedure used by some ALs is to connect a USB keyboard to the Tablet PC, so that both keyboard entry and tablet pen entry are possible in the tablet configuration.

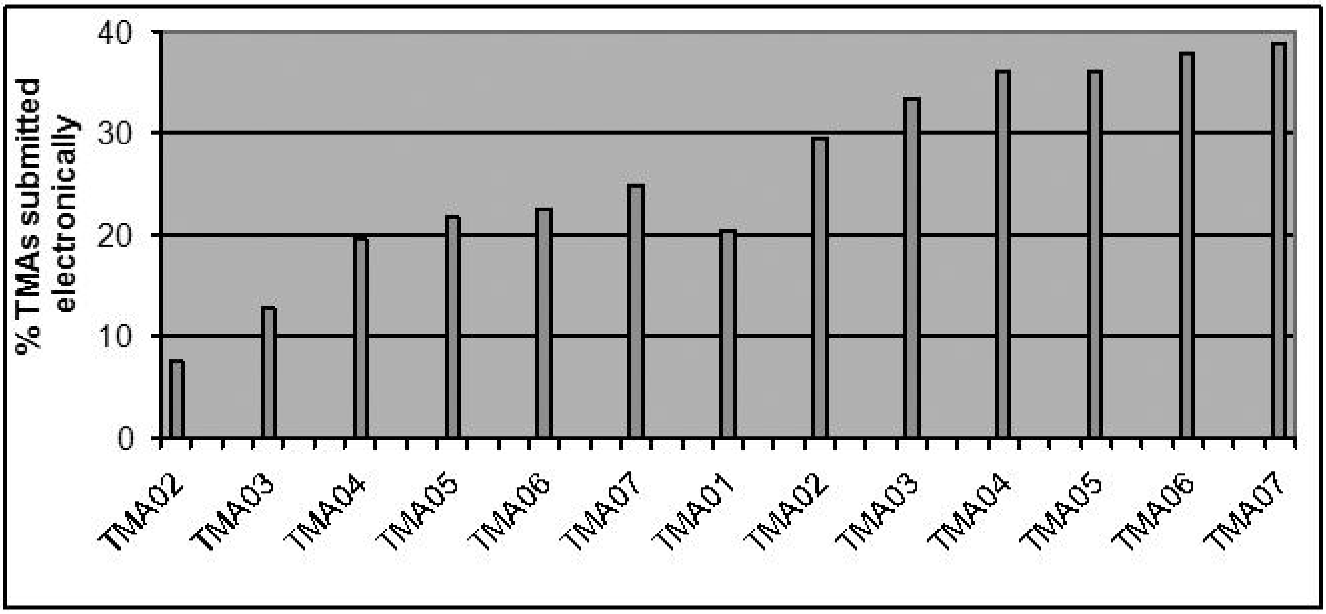

Figure 2: Percentage of TMAs submitted electronically for each assignment during 2006 (shown on the left) and 2007 (shown on the right).

Ink annotation using Microsoft Word
A large majority of the eTMAs were submitted by students as Word documents, and so a second option for eTMA marking is for ALs to use the Ink tools available in the Tablet PC version of Word 2003, which was installed on these computers. The Ink Annotation tool can be used to write with the tablet pen anywhere in an open Word document, and, as with PDF Annotator, it is possible to change pen colour and line width, to erase ink marks, and to reposition and resize comments. It is also possible to use the Ink Comment tool to insert comments in the margin. This is similar to using the normal Insert Comment feature in Word, except that the comments are handwritten in a balloon in the margin using the tablet pen, and these comments can include equations and diagrams. As with PDF Annotator, it is possible to switch back and forth between using the keyboard to enter simple text in the laptop configuration and using the tablet pen to enter equations and figures in the tablet configuration. When the AL has finished marking the script, the file is saved in .doc format for return to the student via the eTMA system.

Ink annotation using Windows Journal
A third way to mark eTMAs with a Tablet PC is to convert the student's file to a Windows Journal file and then to annotate this file using the tablet pen. As with PDF Creator, Windows Journal installs a virtual printer with which any printable file submitted by a student can be converted to a Windows Journal file (.jnt), and this file can then be annotated in much the same way as a pdf file is annotated using PDF Annotator. This option was not suggested to the physics ALs, and none of them apparently discovered or used this method, but this was the approach used by Fisher[4] in another Open University Tablet PC trial with a technology course.

Evaluation
After completion of the 2006 presentation of S207, a brief questionnaire was emailed to the ALs who had participated in the pilot project, and 15 of the 19 participants responded. A more comprehensive questionnaire was emailed at the end of 2007 to the 24 ALs involved in that year's presentation, and 23 of them responded. For both years, information about the number of paper TMAs and eTMAs marked by each AL for each of the course assignments was obtained from the assignment handling database.

Percentage of eTMAs submitted electronically
The percentage of the total number of TMAs that were submitted electronically grew steadily during the project, as shown in Figure 2, and reached 40% by the end of 2007.

Format of the eTMA files submitted
ALs reported that (70%) of the eTMAs submitted in 2007 were word-processed, including the equations and diagrams. About 20% were largely word-processed, but with equations and/or diagrams produced by hand, and scanned images inserted into the document. The other 10% of eTMAs were completely handwritten and then scanned. Most of the eTMAs (83%) were submitted as Word .doc files, but small percentages were submitted in other word-processor formats, as pdf files or as image files.

Marking procedures used by ALs
In 2007 the ALs were approximately equally split between those who converted files to pdf format and then marked using PDF Annotator, and those who marked using Word. Most of the ALs who opted to use Word for marking did not receive any files in other formats, and this may have been because they specifically asked students to submit eTMAs as .doc files. A variety of approaches were used when marking in Word; most ALs used both keyboard and tablet pen entry, but a couple opted not to use the Tablet PC and used a conventional computer for inserting text boxes and comments (using Track Changes). None of the ALs used the Windows Journal application.

Difficulties in learning how to use the marking system

ALs were asked whether they had problems learning how to use the Tablet PC or the associated software. Even though the only information that they had received was the standard user manuals for the computer and the software, there were few reported problems. A few tutors said they would have appreciated more guidance on the conversion of files to pdf format and on the use of PDF Annotator, and one commented that the use of the Print File command in PDF Creator to produce a pdf file was counterintuitive. A couple of ALs thought there should be explicit guidance about how to insert pages into a script for additional comments. During 2007 we produced a document that provided guidance on the use of the Tablet PC for marking and this was distributed to all participating ALs. This document will be available in future years for ALs who are new to this method of marking.

Ergonomic considerations

Six tutors said that it took them some time to find a comfortable way to mark using the Tablet PC. Three of them found that it was difficult to use the Tablet PC while wearing varifocal glasses, and two of them overcame this problem by using single prescription lenses while marking. Two ALs worked with the Tablet PC on their laps and another found that they had to use a lower working surface. One AL found using the Tablet PC so uncomfortable that he minimised use of it in the tablet mode by connecting an external monitor, keyboard and mouse to the Tablet PC and only using pen input for equations or diagrams that could not be copied or referred to. In future it would be appropriate to provide some 'ergonomic' advice as part of the guidance to ALs on the use of the Tablet PC for eTMA marking.

Advantages of using the Tablet PC

The ALs were asked about the advantages of using the Tablet PC for electronic marking compared with paper marking, and the main points they mentioned were:

- the ability to annotate eTMAs in the same way that they would annotate paper TMAs;
- the ability to erase comments, or to revise them; they were pleased that they did not need to use correction fluid or to cross out comments; they thought their comments were often more considered, since they could be changed if necessary after reading a later part of the answer;
- no longer needing to contend with the piles of paper associated with conventional TMA marking; also, the pages can't get out of order;
- the ability to copy and paste comments between different TMAs;
- comments could be more legible – though it may be necessary to write more slowly, or to rewrite comments;
- the ease of inserting relevant parts of the specimen answers;
- several ALs said that eTMA marking requires less time than conventional marking;
- automated addition of marks avoids errors;
- improved turnaround time, particularly for students outside the UK;
- avoids use of the paper-based mail delivery system; it is easier to upload marked eTMAs than to post paper TMAs; eTMAs can be accessed anywhere that there is a broadband connection;
- AL retains copy of assignment on their computer for reference.

Ongoing problems and disadvantages of using the Tablet PC for marking

In addition to the ergonomic considerations noted above, the main ongoing problems and disadvantages mentioned were:

- some ALs found that it took longer to mark assignments electronically;
- converting files to pdf format was tedious;
- it was difficult to trawl through pages to get an overview to ensure that the comments were appropriate, or difficult to lay out pages and compare several scripts to ensure consistency;
- it was inconvenient to switch between different students' files when marking each question as a batch;
- it was not as convenient as paper for marking while waiting in the car;
- ALs found that switching between laptop and tablet modes was inconvenient; some ALs avoided this inconvenience by using an external keyboard connected to a USB port on the Tablet PC;
- it is not possible to cut and paste in PDF Annotator;
- the reliability of electronic submission (compared with postal submission) meant that many students delayed eTMA submission until just before the deadline.

Student feedback

The small amount of feedback that ALs received from students who submitted eTMAs was positive, with most of the comments about the quick turnaround and the ability to submit right up to the cut off time. However, some students did also comment on the clarity and legibility of the comments that ALs made in the returned file.

Overall views about marking eTMAs compared with marking paper TMAs

In 2007, eleven of the 23 ALs expressed a preference for marking eTMAs and eight ALs either said explicitly that they were equally happy with paper TMAs and eTMAs or expressed no preference. Only four ALs indicated a preference for paper marking, and three of these had marked very few eTMAs. Almost all of the ALs were very positive about the pilot project. There were some reservations from those who found that eTMAs took longer to mark – this needs to be reviewed when ALs are more familiar with using this method of marking. A more detailed report on the electronic marking trial can be found on the πCETL website[5].

Future work

In 2006, about 17% of assignments submitted to ALs taking part in the project were eTMAs, and this increased to 32% in 2007. The main reason that the majority of S207 students prefer paper submission is that they lack the IT skills to incorporate equations and diagrams into a word-processed TMA and/or find that producing an eTMA is unacceptably time -consuming. During the 2007 presentation, another πCETL project attempted to increase the number of students submitting electronically by offering students the loan of either a scanner or a digital pen. These systems allow the student to write their assignment answers on paper, but then to convert it to a digital format that can be submitted via the eTMA system.

In 2008 we have extended the electronic marking project to two Level 3 physics and astronomy courses.

Electronic marking with campus-based students
The OU project investigated the use of electronic marking in a distance-learning context, where a major benefit of electronic marking is that electronic transmission of assignments eliminates dependence on the postal service. This particular benefit is not relevant for campus-based students, where paper assignments can be placed in appropriate pigeonholes, but there would still be benefits from using an electronic system that recorded submission and return dates for assignments, that stored marks, and that kept copies of all marked assignments. Academics would also benefit from the elimination of piles of paper assignments, from the ability to download, mark and return assignments anywhere that they have an internet connection, and from all of the other advantages of marking electronically discussed earlier. It would be straightforward to provide campus-based students with access to scanners that could convert handwritten assignments into a single pdf file, so that lack of skills with using word-processing software, equation editors and drawing packages would not disadvantage them.

A πCETL project at Leicester University[6] is going much further, and investigating a paperless degree. So not only are assignments being handled electronically, but also all course materials are provided electronically.

The small amount of feed-back that ALs received from students who submitted eTMAs was positive, with most of the comments about the quick turnaround and the ability to submit right up to the cut off time.

Conclusion
This S207 pilot project has shown that a Tablet PC provides an effective and acceptable method of marking physics assignments electronically – from the viewpoints of both the ALs and the students. ALs used two main methods of electronic marking – annotating pdf files using PDF Annotator and using annotating doc files using Word – and the choice was a matter of personal preference. However, it must be recognized that although Tablet PCs provide a good way of marking physics assignments, their capital cost may inhibit their widespread use for marking Open University assignments.

Acknowledgements
We gratefully acknowledge the contributions of Jonathan Underwood, who set up and ran this pilot project at the Open University until he moved to University College London, and of the associate lecturers who participated in the project and whose feedback was used as the basis of this report. This project would not have been possible without the funding and support provided by πCETL, which in turn is funded by the Higher Education Funding Council for England.

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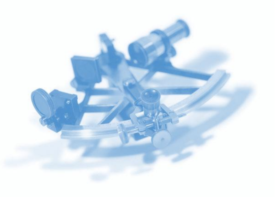
6. See πCETL website: Symons, S., *Paperless degree project* <www.open.ac.uk/picetl/projects/paperlessdegree>.



Online interactive assessment with short free-text questions and tailored feedback

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Abstract

A linguistically based authoring tool has been used to write e-assessment questions requiring short free-text answers of up to about 20 words in length (typically a single sentence). The answer matching is sophisticated and students are provided with instantaneous targeted feedback on incorrect and incomplete responses. They are able to use this feedback in reattempting the question. Seventy-five questions of this type have been offered to students on an entry-level interdisciplinary science module and they have been well received. Students have been observed attempting the questions and have been seen to respond in differing ways to both the questions themselves and the feedback provided. The answer matching has been demonstrated to be of similar or greater accuracy than specialist human markers.

The software described is all either open source or commercially available, but the purpose of this paper is not to advertise these products but rather to encourage reflection on e-assessment's potential to support student learning.

Introduction

It is widely recognised that assessment has a profound effect on student learning[1], although the effect is not always a positive one[2,3]. There has been a recent explosion of interest in 'assessment for learning'[4], in which the focus is on the formative, teaching functions of assessment and which contrasts with 'assessment of learning', where the primary interest is in the measuring, summative function.

A number of literature reviews[5,6] have identified conditions under which assessment supports student learning[6,7]. Two common themes are the role of assessment to motivate and engage students, and the role of feedback. However, if feedback is to be effective, it must be more than a transmission of information from teacher to learner. The student must understand the feedback sufficiently well to be able to learn from it; ie to 'close the gap' between their current level of understanding and the level expected by the teacher[8,9]. Thus the use of the word 'feedback' in the context of assessment becomes aligned with the scientific use of the word, a cyclical process in which a change in one variable leads to a change in the initial conditions.

If a student is to be able to act on the feedback received, it follows that, as well as being sufficiently detailed and framed in a way that the student can understand, it must reach them quickly. However it can be difficult for hard-pressed university lecturers to deliver useful feedback in a timely fashion. One possible solution is to use e-assessment: this offers particular benefits when class sizes are large and so development costs are more than offset by savings of academic time. However opinions of e-assessment are mixed: some people are excited about its potential[10]; others are concerned that e-assessment tasks (primarily but not exclusively multiple-choice questions) can encourage a surface approach to learning[3,11]. This paper describes a project, building on work described in Swithenby's review of screen-based assessment[12], which seeks to develop and evaluate more meaningful e-assessment questions.

If a student is to be able to act on the feedback received, it follows that, as well as being sufficiently detailed and framed in a way that the student can understand, it must reach them quickly.

The work described is taking place at the Open University, as one of a number of 'e-assessment for learning' projects funded by the Centre for the Open Learning of Mathematics, Science, Computing and Technology (COLMSCT)[13].

Background to the current work

The Open University is the global maintainer of the Moodle[14] virtual learning environment quiz engine. Work has been done to improve Moodle question types and reporting, and the OpenMark e-assessment system has been incorporated into Moodle[15]. OpenMark[16] offers a number of question types, allowing for the free-text entry of numbers, simple algebraic expressions and single words as well as drag-and-drop, hot spot, multiple-choice and multiple-response questions. A distinctive feature of OpenMark is the provision of multiple attempts at each question, with the amount of feedback provided increasing at each attempt. If the questions are used summatively, the mark awarded decreases at each attempt, but the presence of multiple attempts with increasing feedback remains a feature. Wherever possible the feedback is tailored to the misunderstanding that has led to the error (see Figure 1). The provision of multiple attempts with increasing feedback is designed to give the student an opportunity to act on the feedback to correct his or her work immediately and the tailored feedback is designed to simulate a 'tutor at the student's elbow'[17].

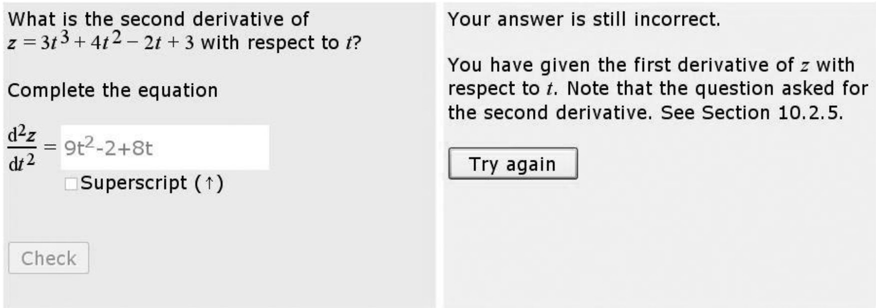

Figure 1: Feedback provided on an incorrect response to an OpenMark question.

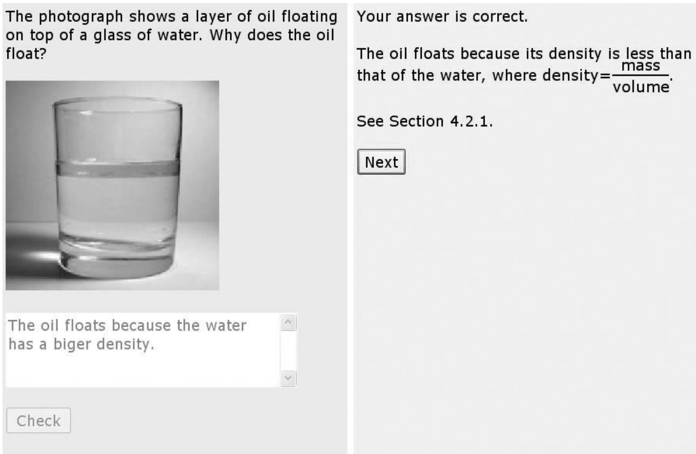

Figure 2: A free-text question, illustrating the correct marking of a response which includes a spelling mistake.

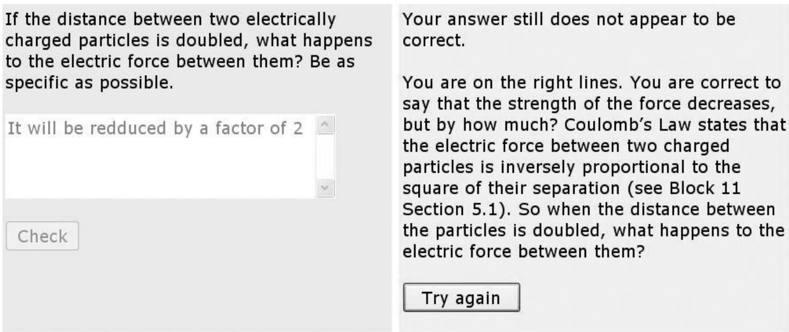

Figure 3: A free-text question, showing targeted feedback on an incorrect answer.

Short free-text questions with tailored feedback

The current project has extended the range of e-assessment questions offered to students via OpenMark to include those requiring free-text answers of up to around a sentence in length (around 20 words). The answer matching is written with an authoring tool provided by Intelligent Assessment Technologies Ltd. (IAT), which uses the natural language processing technique of information extraction and incorporates a number of processing modules aimed at providing accurate marking without undue penalty for poor spelling and grammar. The authors of questions use an interface to the authoring tool which enables mark schemes to be represented as a series of templates.

Accurate marking is possible for many different and sometimes quite complex student responses, taking account of word order when appropriate. So, in answer to the question shown in Figure 2, a response of 'because oil is less dense than water' can be distinguished from 'because water is less dense than oil'. Similarly, a negated form of a correct response will be marked as incorrect (so 'the forces are not balanced' is distinguished from 'the forces are balanced').

A novel feature of our project has been the use of student responses to developmental versions of the questions, themselves delivered online, to improve the answer matching. Previous users of the IAT software[11] and similar products[18] have used student responses to paper-based questions, but this approach assumes that there are no characteristic differences between student responses to the same question delivered by different media, or between responses that students assume will be marked by a human marker as opposed to a computer.

Importance has been placed on the provision of instantaneous targeted feedback. Since the questions are offered to students via OpenMark, students are allowed several attempts, as described above. The feedback for incomplete or incorrect answers (as shown in Figure 3) is generated from within the IAT authoring tool. Targeted feedback has been added for misconceptions and omissions observed in the analysis of student responses.

Seventy-five short-answer questions, assessing the learning outcomes of an introductory interdisciplinary science module, have been authored and refined in the light of student responses. Writing the initial answer matching can be a relatively quick process (typically taking around an hour) but amending it in the light of student responses is much more time consuming, taking more than a day for some questions. However the outcome is questions that can be re-used many times, and which engage students in a more meaningful way than more conventional e-assessment tasks.

Evaluation: human-computer marking comparison

A batch of student responses to each of seven free-text questions were marked independently by six course tutors, by the computer system and by the question author.

To ensure that the human-computer marking comparison did not assume that either the computer or the human markers were 'right', the IAT and each course tutor's marking of each response were compared against:

- The median of all the course tutors' marks for that response;
- The 'blind' marking of the response by the author of the questions.

Responses in which there was any divergence between the markers and/or the computer system were inspected in more detail, to investigate the reasons for the disagreement.

Chi-squared tests showed that, for three of the questions, the marking of all the markers (including the computer system) was indistinguishable. For the other four questions, the markers were marking in a way that was significantly different. However in all cases, the mean mark allocated by the computer system was within the range of means allocated by the human markers. The percentage of responses where there was *any* variation in marking ranged between 4.8% (for Question 1 'What does an object's velocity tell you that its speed does not?', where the word 'direction' was an adequate response) and 64.4% (for Question 13, a more open-ended question: 'You are handed a rock specimen from a cliff that appears to show some kind of layering. The specimen does not contain any fossils. How could you be sure, from its appearance, that this rock specimen was a sedimentary rock?'). However in every case more variation was caused by discrepancy between the course tutors than between the median of the course tutors or the question author and the computer system.

For six of the questions, the marking of the computer system was in agreement with that of the question author for more than 95% of the responses (rising as high as 99.5% for Question 1). For Question 13, the least well developed of the questions at the time the comparison took place, there was agreement with the question author for 87.4% of the responses. Further improvements have been made to the IAT answer matching since the human-computer marking comparison took place in June 2007, and in July 2008, the marking of a new batch of responses was found to be in agreement with the question author for between 97.5% (for Question 13) and 99.6% (for Question 1) of the responses.

Mitchell et al.[19] have identified the difficulty of accurately marking responses which include both a correct and an incorrect answer as 'a potentially serious problem for free text analysis'. Contrary to e-assessment folklore, responses of this type do not originate from students trying to 'beat the system' (for example by answering 'It has direction. It does not have direction') but rather by genuine misunderstanding, as exemplified by the response 'direction and acceleration' in answer to Question 1. The computer marked this response correct because of its mention of 'direction', whereas the question author and the course tutors all felt that the mention of 'acceleration' made it clear that the student did not demonstrate the relevant knowledge and understanding learning outcome. Whilst any individual incorrect response of this nature can be dealt with (in the IAT authoring tool by the addition of a 'do not accept' mark-scheme) it is not realistic to make provision for all flawed answers of this type. In the words of Mitchell et al 'while the characteristics of the set of creditworthy responses may be increased iteratively, algorithms for recognising incorrect science may approach the infinite'.

In acknowledging that computer-based marking of free-text answers will never be perfect, the inherent inconsistency of human markers (where different markers mark the same response in a different way or where one marker marks the same response differently on different occasions) should not be underestimated. If course tutors can be relieved of the drudgery associated with marking relatively short and simple responses, time is freed for them to spend more productively, perhaps in supporting students in the light of misunderstandings highlighted by the e-assessment questions or in marking questions where the sophistication of human judgement is more appropriate.

Evaluation: student observation

Each batch of developmental questions offered to students was accompanied by a short online questionnaire, and responses to this questionnaire indicate that a large majority of students enjoyed answering the questions and found the feedback useful. In order to further investigate student reaction to the questions and their use of the feedback provided, six student volunteers, from the course on which the questions were based, were observed attempting a number of short answer question alongside more conventional OpenMark questions. The students were asked to 'think out loud' and their words and actions were video-recorded.

Five of the six students were observed to enter their answers as phrases rather than complete sentences. It is not clear whether they were doing this because they were assuming that the computer's marking was simply keyword-based, or because the question was written immediately above the box in which the answer was to be input so they felt there was no need to repeat words from the question in the first part of the answer. One student was observed to enter his answers in long and complete sentences, which we initially interpreted as evidence that he was putting in as many keywords as possible in an attempt to match the required ones. However the careful phrasing of his answers makes this explanation unlikely; this student started off by commenting that he was 'going to answer the questions in exactly the same way as for a tutor-marked assignment' and it appears that he was doing just that.

Students were also observed to use the feedback in different ways. Some read the feedback carefully, scrolling across the text and making comments like 'fair enough'; these students frequently went on to use the feedback to correct their answer. However, evidence that students do not always read written feedback carefully came from the few instances where the system marked an incorrect response as correct. Students were observed to read the question author's answer (which appears when the student answer is either deemed to be correct or when it has been incorrect for three consecutive attempts) but not to appreciate that the response they had given was at variance with this. Being told that an incorrect answer is correct may act to reinforce a previous misunderstanding. Given the high accuracy of the computer's marking, this is not a common problem but it is an important one, as it is when a human marker fails to correct a student error.

Future developments

Modified versions of some of the questions developed have been incorporated, along with conventional OpenMark questions, into regular interactive computer marked assignments (iCMAs) which form part of an integrated assessment policy (also including tutor marked assessment) for a new module. These iCMAs are summative but low stakes; their role is to encourage students to keep up to date in their studies as well as providing relevant and instantaneous feedback and an opportunity for students to act on that feedback immediately.

Further information about this project and some sample questions are available on the author's COLMSCT website[20].

Acknowledgements

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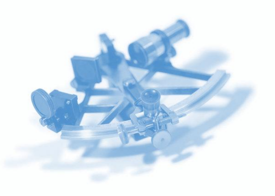

An Integrated Approach to Encourage Student-Centred Learning: a First Course in Dynamics

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Abstract

One of the most significant challenges facing Higher Education today is getting students to take responsibility for their own learning. In Science and Engineering this is complicated by the decline in the mathematical and problem solving skills of students entering university. Several techniques for addressing these issues have been applied to the Dynamics module on the first year Physics course at the University of Manchester over the last two years. These include the use of Just-in-Time Teaching, e-learning and e-assessment, interactive voting systems and peer instruction. We first encourage students to start to construct their own understanding via e-learning and then challenge their understanding during a lecture-based session using an interactive voting system. This is followed by more e-learning, which features formative e-assessment, and by a staff-supervised problem session using the Just-in-Time Teaching approach. Thus we have been able to improve student engagement with the course material and have achieved a significant improvement in examination performance. This paper will describe the implementation of the various new techniques and discuss their advantages and disadvantages.

We first encourage students to start to construct their own understanding via e-learning and then challenge their understanding during a lecture-based session using an interactive voting system.

Introduction

The School of Physics and Astronomy at the University of Manchester has a first year intake of over two hundred students. Like all sciences, we struggle with progression, which we would like to improve. One of the areas where improvement is needed most is at the interface of mathematics and physics.

All Physics students take Dynamics as a core module covering basic Newtonian Mechanics, in their first semester. Traditionally this module has suffered from mediocre student feedback and relatively poor examination results compared with other first year modules. Several initiatives have been tested over the last couple of years to improve the situation. We have aimed to get the students to engage more with the subject and to take more responsibility for their own learning. In 2006-07 we brought in Just-in-Time Teaching, e-learning and e-assessment and in 2007-08 we added peer instruction using an interactive voting system.

Initiatives in 2006-07

Just-in-Time Teaching

Just-in-Time Teaching (JiTT) is a student-led approach to teaching which was originally developed in the USA by Novak et al[1] as a collaborative project between the Physics departments of the IUPUI (Indiana University–Purdue University Indianapolis) and the US Air Force Academy. The idea of the approach is that the content of classes is decided at the last minute and is tailored to specifically address the concepts that the students have misunderstood or are having difficulty with.

When the JiTT approach is used in the USA, the students are required to do *some* preliminary self-study of new material before they attend the class. Having completed the self-study, they undertake an on-line assignment which assesses their understanding of the new material. Usually the on-line assignments focus on the concepts involved. The students submit their on-line assignments just a few hours before the class enabling the instructor to obtain an appreciation of the students' difficulties and misconceptions. He/she is then able to structure the content of his/her class according to the needs of the students. The class preparation has to be done at the last minute before the class is due to be delivered, hence the title 'Just-in-Time Teaching'.

The Just-in-Time approach was used with relatively small class sizes at IUPUI and elsewhere, whereas, as mentioned earlier, our student cohorts are in excess of two hundred. Another difference we perceived between IUPUI and our own institution was one of culture; the notion of pre-lecture study is quite alien to most UK students, so initially we adopted a slightly modified JITT approach.

Modified JiTT approach
The Dynamics lecture course runs for 11 weeks. Previously it had been delivered in a very traditional manner with two one-hour didactic lectures per week plus a one hour workshop where the students solved pre-set problems supported by a member of staff and post-graduate students. This was changed; the didactic lectures and workshop were replaced by one 'overview' lecture at the beginning of each week, followed by a Just-in-Time Response and Problem (JIRP) session at the end of the week. The overview lecture was used to 'set the scene' for the week. It was not the usual in-depth lecture but rather it was intended to give the students a brief introduction and overview of the material to be studied that week. The students were expected to follow up the overview lecture with several hours of self-study using a very comprehensive set of e-learning material provided on the university's Virtual Learning Environment (VLE), WebCT. Once they felt reasonably confident that they had understood the material, they were required to do an on-line assessment. This had to be submitted by 2.00am each Friday morning. The results of the assessment were reviewed by staff early Friday morning and preparation undertaken for the JIRP session which was held in the afternoon. The students were split into two groups for these sessions, each run by one member of staff.

The combination of the overview lecture, the on-line work and the JIRP session constituted a weekly cyclic process as depicted in Fig 1, with the normal small group (4 students) tutorials completing the loop.

E-Learning
All the material that the students were expected to learn for the Dynamics module was provided on WebCT. The lecture course was divided up into eleven topic areas corresponding to the eleven weeks of the course. For each topic area a rich suite of e-learning material was provided. This consisted of not just normal textual material but also 'talklets' and 'physlets'. Talklets[2] are small screencasts of animated PowerPoint diagrams with voice-overs. Over sixty talklets were produced and were used to explain difficult concepts or solutions to example problems. The physlets[3] are Java applets consisting of animations used to simulate concepts that it might be difficult to appreciate from other static media such as textbooks, eg the cycloid described by a point on the rim of a wheel as it rolls along the ground and the notion that its velocity is momentarily zero when it is in contact with the ground. Interactivity was also incorporated into many of the physlets.

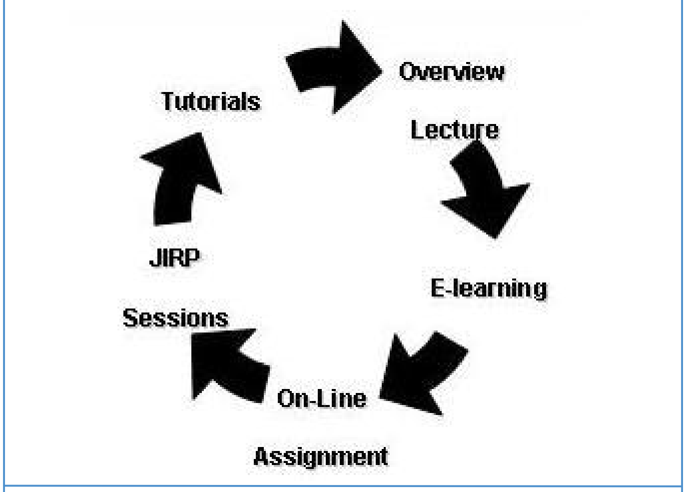

Fig 1. Weekly cyclic process for the Dynamics module

On-line Assessments
A commercial web-package called 'Mastering Physics'[4] was used for the weekly on-line assignments. 'Mastering Physics' is provided as a companion to the first years' core textbook, 'University Physics' by Young and Freedman[5], which all our first year students are required to purchase and provides them with an access code for the website. The package contains an extensive problem library organised by topic area, correlating directly with the chapters of the book. Weekly assignments were produced by selecting suitable problems from the library. Each assignment consisted of between 4-6 problems. The beauty of the package is that it provides hints for the students should they need them and tailored feedback on incorrect answers, since it has the capability to analyse algebraic answers and apply malrules (a malrule is an algorithm that gives an incorrect answer to a problem eg a differentiation where an integration is required.) The package automatically marks the assignments. Penalties for using the hints can be applied to the overall marks achieved and these can be set by the instructor. The instructor can also set the maximum number of attempts allowed for each question.

Once all the students have submitted an assignment, or the deadline has passed, Mastering Physics provides the instructor with a comprehensive analysis of the results. Information provided for each problem includes:

- the percentage of students who answered correctly
- the percentage of students who requested the answer
- the average number of wrong answers per student
- the average number of hints used per student.

Further diagnostics provided include histograms and cumulative frequency graphs of the time spent on the assignment and the overall scores. A gradebook provides a record of every student's marks for all the individual assignments, thus enabling weak students to be quickly identified. A list of the incorrect answers that students gave is also provided. Students are also able to feedback comments on each of the problems and grade them in terms of how difficult they found them. This wealth of information enables the students' difficulties, common misunderstandings and/or misconceptions to be easily identified, as well as the effectiveness of the questions, to be judged. This proved to be very important in developing our material.

JIRP sessions
The implementation of the JiTT approach requires the content of the JIRP session to be determined by the feedback obtained from the on-line assessment, giving very little preparation time on the Friday morning for the JIRP session in the afternoon. This meant that a few different scenarios had to be prepared for in advance. Different discussion ideas and problems had to be ready beforehand so that the most appropriate ones could be 'picked off the shelf' at the last minute.

Some time was usually spent during the first part of the JIRP session discussing the Mastering Physics problems that most students had had greatest difficulty with and then similar, often slightly more complicated problems on the same themes or concepts were introduced.

Outcomes of the 2006-07 initiatives
A very positive outcome of the 2006-07 initiatives was that examination performance improved significantly with the average examination mark increasing from 50% in the previous year to 67% in 2006-07. Also the tail of the Normal distribution of marks was significantly reduced, with the percentage of students failing the examination, (ie achieving less than 40%) decreasing from 32% in 2005-06 to only 10% in 2006-07.

Approximately 95% of the students submitted the electronic assignments each week. This was a much better submission rate than for their normal tutorial work, but was probably due to the fact that the Mastering Physics assignments were credit bearing (worth 15% of the module marks). Students obtained full credit for an assignment provided that they achieved at least two thirds of the average mark for that assignment. This meant that the assessment could remain formative, but there was an additional driver to return the work.

However, the student feedback was disappointing. The new approach required the students to take much more responsibility for their own learning and this was contrary to their expectations and their previous experience at school or college. Many of them objected to having to do this. Although there was favourable feedback on the talklets, some students commented that they found the e-learning component very solitary. One factor that did not help was that all the other first year modules were still being taught in a very traditional manner and the students did not understand why the delivery of Dynamics was different.

The majority of students did not like using Mastering Physics. There were teething problems and sometimes the students found the feedback that they got for incorrect answers not very helpful or even misleading. Also not all the problems had hints associated with them and students found this frustrating if they did not know where to start on a problem.

As staff, we found that the penalty we had set for using the hints was too low (only 2%), leading to some students merely opening all the hints without really trying to understand what the problem was all about.

The JIRP sessions quickly became poorly attended. We found it difficult to pitch the content such that everyone was satisfied. Those students who had not managed to solve the Mastering Physics problems would have preferred the whole session to be devoted to going over the problems whereas other students who had successfully completed them, would have found this a complete waste of time. By compromising and only discussing a few of the Mastering Physics problems at the start of the session and then following this with more complex problems, we failed to really satisfy anyone.

The overview lectures were also not well attended. Once students realised that all the material was on WebCT the attendance dropped to about 50%.

Initiatives in 2007-08
Several changes were made in 2007-08. Firstly, we changed the structure of the overview lecture given at the beginning of each week, quite dramatically. It had become clear from our experiences in 2006-07 that if all the learning material is placed on the VLE, there needed to be a reason for students to attend the lecture. They needed to gain more from it than they could by just studying the material on WebCT. A survey by Hake[6] indicates that interactive lectures are a more effective way of teaching than traditional lectures. So in 2007-08, we made the format of the dynamics lectures much more interactive by introducing an interactive voting system and peer instruction.

Interactive Voting
Interactive voting is the process whereby students answer, or 'vote' on, a question, very often a multiple choice question, using an electronic handset. The handset transmits a signal to a receiver which in turn inputs directly to the instructor's computer. Once all the students have responded a bar chart or histogram of the distribution of answers can be displayed on the screen at the front of the lecture theatre. Excellent reviews of the use of interactive voting systems have been published by Duncan[7] and Bates et al[8].

There are two types of interactive voting systems on the market, infra red (IF) systems which only transmit data one-way from the handsets to a receiver, and radio frequency systems (RF) which transmit data in both directions, ie back and forth between the handsets and a transmitter/receiver. We chose a radio frequency PRS (Personal Response System) system manufactured by Interwrite[9]. Although more expensive than the IF systems, radio frequency systems have many significant advantages over the IF systems, eg:

- There is no need for several receivers to be permanently fixed in lecture theatres
- RF systems are readily portable
- The response time is faster
- RF systems can cope with several hundred students
- IF systems require a separate screen to display a 'response grid' which is needed to enable students to check if their answer has been received. With the two-way communication RF system a signal is returned to the handset and 'answer received' is displayed on the handset.

Two hundred and sixty handsets, known colloquially as 'clickers', were purchased. They were each labeled with an individual bar-code and every first year student was issued with one at the beginning of the first semester. They were issued by the library in exactly the same way that books are issued to students. Students were then responsible for bringing the clickers to each lecture. This meant that valuable time was not wasted at the beginning and end of each lecture distributing and collecting clickers. With over two hundred students this would have been totally impracticable. This process worked well, and we only had two clicker casualties during the semester, one which was broken whilst being in a student's bag and a second one which was lost.

Peer Instruction
Peer instruction was originally developed by Eric Mazur at Harvard University[10]. The idea is that students teach one another. A multiple choice question is put to the students. They select an answer individually using their clickers. They

are instructed not to confer with their neighbours but to make up their own minds about their answer. What happens next depends on the distribution of responses.
If the majority of students give the correct answer, the instructor is reassured that most of his/her audience has understood and is following him/her satisfactorily, and a very brief explanation may be given for the minority of students who gave an incorrect answer. If, however, there is a significant number of students who give an incorrect answer, then peer instruction comes into play. The students are asked to turn to their neighbours in the lecture theatre, either alongside them or in the rows in front or behind them and find someone who gave a different answer from themselves. Then they must try to argue their reasoning for their answer with one another. After a minute or two's discussion, and much noise in the lecture theatre, the students are asked to vote again on their clickers. Usually the percentage of correct answers will have increased significantly.

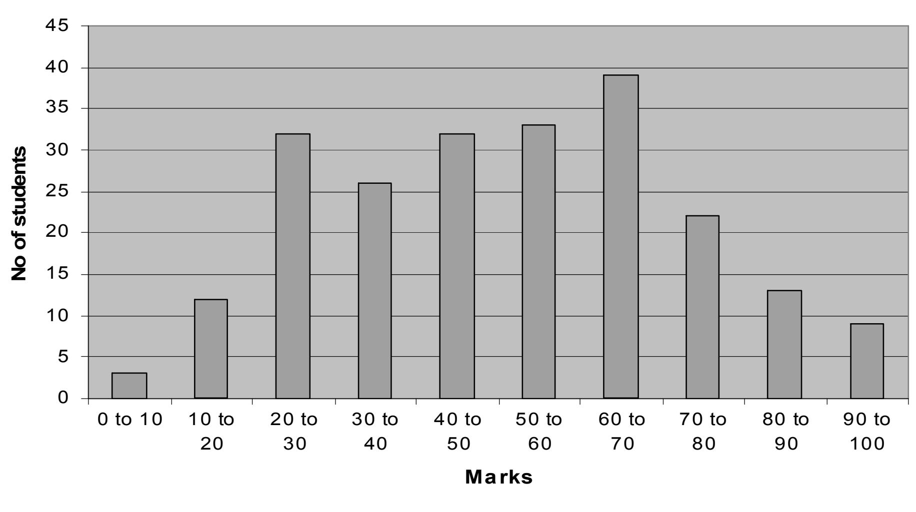

Figure 2: Examination Marks Distribution 2005-06

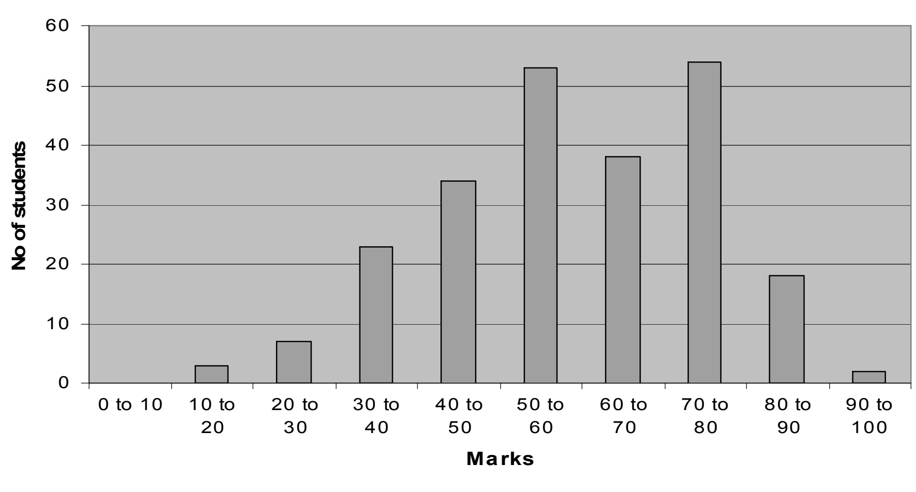

Figure 3: Examination Marks Distribution 2007-08

Peer instruction was used in the 'overview' lectures each week, and the length of the lectures was extended to two hours (with a ten minute break in the middle). Generally between 4-8 clickers questions were included in a lecture.

We also took the opportunity to introduce the idea of pre-lecture reading despite our reservation about doing this the previous year. Students were given a reading list of the required pre-lecture reading for each lecture at the beginning of the semester. This was sometimes textbook reading but more often it was study of the material on WebCT. The benefits of this were two-fold:

(i) It provided a good form of directed self-study
(ii) More time was freed up for peer instruction and the inclusion of more lecture demonstrations.

Familiarity with the subject matter set was assumed when the lecture was delivered. Very often lectures commenced with a 'clicker' question based upon the pre-lecture reading.

Clicker questions were also sometimes linked to lecture demonstrations by asking the students to predict the outcome of a demonstration by voting on it before it was performed. A good example of this is the classic monkey and the hunter[11] projectile motion demonstration. Generally the more counter-intuitive the clicker question the better, as these really test students' conceptual understanding. However, on two occasions during the semester, the percentage of correct answers to a clicker question decreased rather than increased after the peer discussion. The problems in question were particularly tricky counter-intuitive ones. Obviously in these instances it was clear that the students were lost and significant further explanation was required. Nevertheless, this demonstrates the usefulness of the feedback provided by the interactive voting system.

Improvements to On-line Assessments

We made significant improvements to the Mastering Physics assignments. The flexibility of the package enables problems to be adapted and modified, and new problems added. So for 2007-08 hints were added to all the problems and some of the feedback for incorrect answers was modified. In some instances we also changed the notation used so that it was completely compatible with that used in the lectures. This helped enormously and the students' feedback was much more positive.

JIRP Sessions

In response to the student feedback from the previous year we changed the structure and format of the JIRP sessions. We split the students into four separate groups (each facilitated by a single member of staff) as opposed to two groups previously. This year we made no attempt to go over the Mastering Physics problems in the JIRP sessions. Instead a set of new problems was prepared and then a number of these were selected at the last minute, the selection being informed by the analysis of the Mastering Physics assignment results. Students worked through these together in small groups.

Outcomes of Changes made in 2007-08

The average examination mark was 59% this year and although not quite as high as in 2006-07 was still higher than the original 50% average prior to the introduction of the Just-In-Time Teaching approach. The most significant change in the examination results over the last two years has been the increased progression rate of students as a result of the reduction in the tail of the distribution of marks. This can be seen by comparing Figures 2 and 3 which show the examination marks distributions for 2005-06 and 2007-08 respectively. In 2007-08 only 14% of students failed to attain the pass mark of 40% compared with 32% in 2005-06.

Conceptual questions were introduced on the examination paper for the first time in 2007-8 and we intend to gradually increase the proportion of conceptual questions in future. We are trying to move the students away from the 'plug and chug'[10], ie memorising algorithms, approach to problem solving where they expect all tutorial problems (and exam questions!) to be very similar to those given as examples in lectures. This alternative approach is quite different from their prior experience and they find it quite challenging.

The feedback from the students was very much more positive in 2007-8 as a result of the changes made. The majority of students enjoyed the interactive lectures and peer instruction to the extent that they have asked for the clickers to be used in other lectures. Attendance was generally around 70% which was much better than in the previous year.

Some of the comments made by the students were:

- *"The interactive lecture was a really good idea. It helped to be able to get direct feedback about questions and also to be able to discuss ideas with fellow students."*
- *"Clicker questions kept the lecture interesting and helped me to understand material and spot problem areas."*
- *"Clickers make lectures more enjoyable and interactive. I find it beneficial and more intellectually stimulating to be able to participate in lectures."*
- *"I found the clickers really enhanced my learning as areas that weren't understood were picked up on."*
- *"Clickers were a good idea: they showed how many people understood something; often people won't put their hands up to show they don't understand something. This was an anonymous way of doing this."*

These comments reflect the benefits of the interactive lecture. Students became much more active participants in the lecture. With traditional didactic lectures there is no guarantee that learning is actually taking place because generally there is only one way communication, ie from the lecturer to the students. Two way communication is required in order to know whether the students are actually learning anything. With small class sizes this is relatively easy using the standard 'question and answer' technique but with large lecture groups it is not possible to use this technique effectively. The interactive voting process goes some way to overcoming this problem by providing instantaneous feedback on the students' understanding during the course of the lecture. This enables misconceptions to be resolved immediately.

Students appreciated the anonymity of the voting system. They felt that they were able to participate without the fear of embarrassment if they answered a question incorrectly. With large lecture groups generally only a very small minority of students will be brave enough to answer, whereas with the clickers everyone can participate and it gives the instructor a much better appreciation of the level of understanding across the whole group.

Students appreciated the anonymity of the voting system. They felt that they were able to participate without the fear of embarrassment if they answered a question incorrectly.

The clicker questions also break up the lecture thus helping to reduce attention 'fade'.

A minority of students were not in favour of the clickers. The following comments indicate the general theme of the negative responses received:

- *"Clickers waste a lot of time. Could have gone through things in more detail in this time."*
- *"A lot of extra work was needed outside of the lecture."*

These two comments highlight one of the aspects of peer instruction which can be perceived by some as negative. However, we do not see them as such. In fact the concepts are actually investigated more thoroughly using this approach. It is true that one has to reduce the amount of material that is presented within the lecture, but it does encourage students to do more self-study outside the lecture.

One of the challenges of this approach is managing the students' expectations. Students entering Higher Education in the UK are not independent learners. The ideas of pre- (and even post-) lecture reading and constructing their own understanding are new to them. When we started making changes to the delivery of the Dynamics module we were very wary of introducing the pre-lecture reading. However, interestingly, our experience was very positive. As we were able to monitor students' use of WebCT, when the pre-reading was based on the WebCT material we could see that a good proportion of the students were in fact doing it. This was also reflected in the responses to the 'test' clicker questions given at the beginning of lectures. Indeed, on a week when no pre-lecture reading was prescribed, students made enquiries as to what they needed to read that week. Although there were some students who did not do the pre-reading, it was extremely encouraging that many took it quite seriously. We would suggest that if one expects students to do pre-lecture reading from day one, they are much more likely to accept the idea and just assume that this is the way that university learning works. First year students need pointing in the right direction as to how and what to study and this would appear to be a good way to start. Until entering university their learning experience was very much prescribed by their teachers at school/college and it is suggested that we may be expecting too much of them if we do not guide them more initially.

Other challenges of the interactive lecture are:

(i) Producing good thought-provoking clicker questions which offer sufficient challenge to the majority of students without being impossibly difficult, can be quite difficult and time consuming. Fortunately question banks do already exist. Mazur[10] provides an excellent resource in the form of a CD supplied with his book. The University of Edinburgh[12] also maintains a comprehensive question bank. Text-book publishers, such as Pearson, also often have collections of clicker questions available.

(ii) The level of background noise during a lecture can increase and can be more difficult to control. Duncan[7] also noticed this phenomenon. One minute you are encouraging the students to discuss issues with their neighbours and then the next minute you want them to be quiet whilst you are talking. In a large lecture theatre use of a microphone is essential when you want to draw the peer instruction component to a close. It is also important to agree some ground rules about this with the students at the beginning of the course so that they understand the format of the lecture.

Conclusions

Introduction of several different teaching strategies into the dynamics module over the past two years has resulted in an integrated approach which challenges students' conceptual understanding and encourages them to take more responsibility for their own learning. Students engagement with, and conceptual understanding of, dynamics has improved leading to better exam performance and increased progression rates.

When introducing e-learning into the delivery of a module one needs to consider carefully the impact it may have on attendance in lectures. Lecture format and content may need to be changed so as to provide more 'added value' than the normal traditional lecture. One way of doing this is the use of peer instruction using an interactive voting system.

There is a drawback to our approach as well: it is not efficient with staff time, and requires probably slightly more staff effort than standard teaching. However, on balance we feel that the positive outcomes achieved so far justify the extra effort.

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The use of electronic voting systems to engage students in outreach activities

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It is now widely recognised by all stakeholders that outreach activities may play a significant role in the sustained viability of our disciplines and our departments

Abstract

This paper discusses the use of electronic voting systems specifically in a range of outreach contexts. The Department of Chemistry at the University of Reading and the School of Chemistry at the University of Southampton are actively involved in delivering outreach activities at primary and secondary school level with a view to inspiring a new generation of budding chemists. Voting systems are successful in engaging students across all age groups as demonstrated by our experiences with youngsters aged 4 to 18. They are especially effective at breaking down the barriers of non communication thrown up by students when faced with a difficult question and encouraging the participation of even the most reticent teenager.

Introduction

There are numerous brands of electronic voting systems (EVS) now available on the market,[1] and they are finding use in a range of educational contexts.[2] While a number of innovators have extolled the virtues of such technology in supporting physical science teaching at HE level over recent years,[3] the establishment of EVS as an integral component of our teaching, particularly in chemistry,[4] has yet to become embedded.

It is now widely recognised by all stakeholders that outreach activities may play a significant role in the sustained viability of our disciplines and our departments.[5,6] Outreach may involve students of all ages, and can include visits by university personnel to schools as well as visits by pupils to universities. Although a number of factors are involved, it seems unlikely that the expansion of outreach activities across the country has not played some part in the increase in numbers seen in a number of chemistry departments in recent times. Perhaps more evidence is needed to convince the sceptical scientists among us, but anecdotally at least, it seems fair to say outreach activities are beneficial to all involved.

Our positions in chemistry at Southampton and Reading, supported by funding from the RSC's 'Chemistry For Our Future' programme,[7] allow us to champion new approaches to teaching and have afforded us the opportunity to experiment with EVS both in undergraduate teaching and in schools outreach activities. The latter of these is the focus of this article, although it should be noted that we do make youngsters aware that these 'zappers' are actually used in our undergraduate teaching,[8] and this is perhaps part of their attraction to the participants. One might ask the questions 'How can EVS be used to enhance outreach activities?' and 'Why is this beneficial to HE?'. We hope these questions will be addressed in the following discussion of a number of case studies taken from our repertoire of outreach activities.

Case studies

Classroom activities

Although there has been some focus on the use of undergraduate teaching space for in-house outreach activities, there will always be a place for HE staff in the classroom. The portability and versatility of EVS makes them an invaluable tool for enhancing communication with youngsters across the age range. At Southampton, EVS have been taken to schools and used to support the delivery of an activity on biofuels to pupils at Key Stages 3, 4 (GCSE) and 5 (A-level). Questions asked range from those intended to spark debate to those that test knowledge and understanding either before or after the main body of the activity.

Many students, even at 6th form level, are reluctant to answer questions and share their views, particularly when they find a stranger at the front of their classroom. The use of EVS acts initially as an ice-breaker, with all pupils able to express an anonymous opinion *via* their handset. With results being displayed in the form of a bar or pie chart, many pupils suddenly find their tongues, enquiring 'Who thought that?!' of any unexpected answers. Suddenly the seed of the discussion has been sown, and pupils are engaged in the activity.

The introduction of 'How Science Works' as a core component of QCA specifications[9] for the teaching of science at all levels of secondary education means that all students need to develop an understanding of 'the thinking behind the science'. By taking a snapshot of the youngsters' thoughts and immediately discussing the outcomes with them, we are able to tackle a particular issue head-on and add a useful educational dimension to our outreach activities.

The Great Science debate
The use of EVS is ideal for gauging the opinion of a large group in support of or against a particular argument relating to a given topic. At Reading, EVS have been used in a popular science debating activity with pupils of a range of ages and abilities, from Year 7 to Year 13. The activity is intended to engage young people in scientific topics relevant to everyday life, such as nuclear power, biofuels and GM foods, in addition to developing their skills in investigating and producing evidence to back up their opinions. These are key areas identified in the science curricula from Key Stages 2 to 4.

We have run several of these debate events, both in school and on campus, in which pupils research and formulate arguments within teams and then compete to convince the audience in a discussion of the issues. The audience opinion is polled using EVS both before and after the debate and the winning team is decided on the swing of votes in their favour.

As discussed earlier, the anonymity of the system ensures that all pupils feel able to express an opinion, even if the topic is particularly controversial. The speed at which this data can be assimilated and displayed is also a great benefit, allowing both the audience and the debating team to gauge the general feeling in the room. Since many of these events involve large numbers of pupils, the audience for a particular debate is essentially made up of teams who are debating other topics. Using EVS before the debate helps to engage these pupils in listening and actively thinking about the issues presented, rather than just sitting and waiting for their turn. The competitive aspect is also enhanced, as teams can see the scale of the task ahead of them. Witnessing the eloquence and passion that pupils exhibit about scientific concepts they may previously have regarded as boring is a joy to see.

Quiz challenge
Youngsters in all age groups quickly make the link between an activity using EVS and the popular TV quiz *'Who Wants to be a Millionaire?*', and the technology presents the opportunity to run quizzes in a number of different styles. Undoubtedly there is an element of fun in such activities, but the importance of fun in any outreach activity should not be underestimated, as evidenced by the high levels of engagement observed. Traditional quizzes, typically involving some sort of written activity, can quickly alienate some participants and lead to a dilution of the message the outreach activity is intending to convey.

The questions used in quizzes may be designed to cover aspects of the science that was incorporated into the outreach activity to reinforce learning and identify strengths/weaknesses in the delivery of the event. By including questions on science in the media and famous scientists, we can add weight to our 'sales pitch' that science is important in all of our lives and that scientists have a major role to play.

Paperless surveys and feedback
Anybody engaging in outreach work will be familiar with the requirement to evaluate the impact of the activities, which usually results in a pile of forms which are time-consuming to fill in and analyse, the whole process being demotivating for participants and facilitators alike. EVS can be used to poll answers to evaluatory questions posed to the entire cohort in a short timeframe. By asking questions about the effectiveness/enjoyment of different components of the event, the user can ascertain what works and what doesn't in order to assist planning for future events in an expedient manner. One may choose not to review bar charts of data during the polling session, with the software normally allowing the collection of data in a 'review only' format for later inspection.

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The process of compiling the data into easily interpreted graphical reports with statistical summaries is in most cases almost a 'one-click' procedure, with the use of spreadsheets allowing the user to discern the subtleties hidden in the data. For instance, one can find out about the future plans of the participants by asking the question 'Before today, how likely were you to do a chemistry degree?' before gauging the impact of the outreach activity by asking 'How much more likely are you to do a chemistry degree after today's event?'. It is then very easy to identify how effective your activity has been at selling chemistry to those with different levels of interest prior to the event, without having to dig through written evaluations for the appropriate evidence.

Conclusions

Discerning the true impact of EVS as a tool in delivering outreach activities is a difficult task, but we can identify clear benefits, many of which have been discussed above. Key features are the enhanced level of engagement of all students in a deeper level of thinking, and the ability for the facilitator to give immediate feedback based on student responses. The participants in the outreach activity leave with a clearer understanding and recall of the message they were intended to receive. Whether that message is one with a scientific basis, or a sales pitch regarding the value of studying science at a higher level, it appears that EVS can play a significant role in enhancing the impact of any outreach activity.

References/Notes

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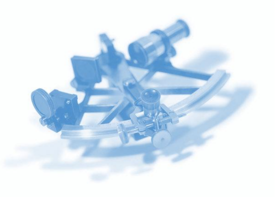
9. To find out more about the QCA guidelines for How Science Works, see: <www.qca.org.uk/qca_9437.aspx> (accessed on 16/07/08).

Key features are the enhanced level of engagement of all students in a deeper level of thinking, and the ability for the facilitator to give immediate feedback based on student responses



Jersey Schools Science Week: An outreach case study

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Abstract
During a single week the combined Bristol Centres for Excellence in Teaching and Learning (CETLs) outreach team of 8 scientists worked in the island's primary and secondary schools, delivering lectures and running workshops, thus forming the first 'Jersey Science Week'. They also gave demonstrations and the opportunity for hands-on investigation using their Mobile Teaching Unit. The number of students engaged during the week is impressive on its own: they had contact with 22 schools and approximately 4500 students. This case study gives the background to the ambitious event and the lessons learnt for future events of this scale.

Background to Combined CETLs' Outreach
The combined Bristol CETLs (Chemistry: Bristol ChemLabS and Medical Sciences: AIMS) were given an additional sum of money to that of the original CETL bids from which the Mobile Teaching Unit (MTU) was created. The main purpose of this bespoke mobile teaching laboratory on an HGV Class 2 lorry is to provide postgraduate surgical skills training away from the University and on location in hospitals. When not in use for this prime purpose it is available for outreach work.

The Bristol ChemLabS School Teacher Fellow[1,2] in collaboration with the Outreach Director had previously developed and used a suite of primary workshop experiments[3] over a two year period and an age adaptable lecture demonstration entitled 'A Pollutant's Tale' [4] that had already been given well over 350 times, mainly to school audiences. The AIMS CETL Teaching Assistant had also developed subject specific workshops.
Prior to the Jersey Science Week there had been five one day events when joint outreach had taken place, three secondary school visits, one primary school and a regional science festival. The mixture of human biology sessions in the MTU and either primary chemistry workshops and assemblies or human biology and chemistry lecture demonstrations had already proved a winning combination. In primary schools every pupil in years 4-6 in a large rural primary school had enjoyed a demonstration assembly and at least 1 hour of practical work. The secondary schools' science days had seen an average of 700 students plus their teachers engaged per day. The Jersey Education Department was approached by Bristol to have all three types of engagement running simultaneously with the aim of enthusing, engaging, educating and entertaining as many students and their teachers as possible.

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What was the engagement?
From March 31st to April 4th 2008 an outreach team from the University of Bristol made up of scientists from the two University of Bristol Centres for Excellence in Teaching and Learning (CETLs), Bristol ChemLabS and AIMS, visited the Island to undertake an ambitious programme of outreach work.

During the week the team worked in primary and secondary schools, delivering lectures and running workshops. They also gave demonstrations and the opportunity for hands-on investigation in their MTU. The number of students engaged during the week is impressive on its own: they had contact with 22 schools and approximately 4500 students. However it was the feedback that we received on the quality of the work that confirmed the value of the week.

The one hour lecture demonstration 'A Pollutant's Tale' was given 19 times in five days to audiences totalling more than 3100 students from Year 7 to Year 13 by Tim Harrison the Bristol ChemLabS School Teacher Fellow. The demonstrations involved in this popular lecture are the sort of experiments that turned many of the readers of this article onto science in the first place. They included the classical demonstrations with liquid nitrogen, dry ice, oxygen foam, minor explosions and colour changes.

The demonstrations were made appropriate to the audience age group as Harrison has had more than 25 years teaching experience at secondary state schools. This event is only one of a menu of outreach activities aimed at secondary school students developed by Bristol ChemLabS.[6]

The primary engagements involved whole school assemblies on the topic of 'gases in the air' and hands-on chemistry workshops where pupils in Years 5 and 6 from 10 separate primary schools had the opportunity to develop their measuring, investigatory and team work skills whilst working alongside postgraduate chemists. Dr. Alison Rivett of Bristol ChemLabS gave the assemblies using demonstrations taken from those used in the secondary lecture demonstrations but with a simplified background 'chemical story'.

The workshops themselves comprised a circus of three experiments taken from a simplified iodine clock investigation, the (gravimetric) determination of the sugar content of fizzy drinks, an investigation of acid concentration with magnesium and polymers (slime and polymorph). In each host school the school hall was converted into a 'science laboratory' for the day. Lab coats, safety glasses and gloves were provided for all participants and their teachers. The need for the availability of several experiments was mainly for the sanity of the postgraduates who would have had thirty 35-40 minute practicals to introduce and supervise in the week!

The postgraduate chemists involved were all very experienced chemistry communicators and had been through the Science and Engineering Ambassador Scheme (SEAS)[5] as around 200 PG chemists had in the last 2-3 years at Bristol.

In all 1200 primary pupils saw the assemblies at the host schools and 500 pupils had the opportunity of 'doing science' in the workshops during the week[7].

Due to the small size of the Jersey roads, having arrived on the Island by ferry the MTU and the AIMS outreach team was based on-site at a single school for the entire week with schools bringing students for the teaching sessions. The team comprised of Dr. Lauren Hughes, a teaching assistant at the University of Bristol who is experienced in undergraduate and science communication in the Department of Physiology and & Pharmacology and Mr. Pete Dickens, a technician in the department. Throughout the week students from 9 schools attended sessions in the MTU, these ranged from Year 3 to Year 13. The majority of the teaching targeted Biology A level and BTEC students studying human biology as part of their courses. Between 5 and 6 sessions were run each day, totally 25 sessions in the week. The MTU offers teaching in small groups, seating 20 students at a time, which allows a lot of interactions with the team and students. Over the week 270 students visited the MTU, with nearly half of these students (112) receiving two sessions either back-to-back or on separate visits in the week.

The two A level, BTEC and GCSE sessions offered were one-hour long sessions titled 'The Cardiovascular System' and 'The Respiratory System' focusing on the anatomy and physiology of the two systems of the body. Each session involved hands-on teaching using anatomical models and X-rays and physiological equipment for students to listen to their own hearts, record their ECG and test their lung function. Within the sessions students learnt how to generate scientific questions and how to go about answering them by being able to generate their own physiological data within the mobile laboratory which could be analysed back in class.

Within the sessions students learnt how to generate scientific questions and how to go about answering them by being able to generate their own physiological data within the mobile laboratory which could be analysed back in class.

The sessions run for primary students were along the same theme with Year 5 and 6 students learning about 'The Heart' and Year 3 and 4 students attending a session on 'What's Inside My Body?' These were 40 minutes in length and the students enjoyed being able to explore inside Anatomy man with his removable organs and learn about bones with Skeleton man.

All of the sessions in the MTU offered students opportunities to see, whether via video clips or actually interacting themselves with pieces of equipment including a spirometer and an ECG machine, what they would otherwise not have had the chance to use in class. The sessions also served as useful revision running up to AS/A level exams as highlighted by comments by a number of the teachers, and they also provided the teachers with some refresher facts and further insight into Physiology.

Why Do Outreach on Jersey?
There were a number of drivers for this particular exercise apart from the usual desire to engage with school students to promote the sciences:

1. This was an opportunity to work with a group without a 'local' University Chemistry department in the British Isles.

2. It was hoped to be an exemplar of a strategy to impact on a 'harder to reach' community.
3. As a feasibility study (financially and logistically) to inform us for future undertakings such as a similar exercise within continental Europe.
4. To compare the approach taken with outreach undertaken in a week on the island of Malta in 2007.
5. Jersey was a 'blank sheet' so it should be easier to assess both short and long term impact of such activities. We were told that very few students go on to read degrees in the chemical sciences as there are not many opportunities for employment as such on the Island.
6. It was the first time that we took the MTU away from the UK mainland.
7. To increase aspirations amongst the Island's potential young scientists. The school students have little contact with scientists at higher education establishments and it is far easier for the scientists to go to Jersey than students in great numbers to go to the mainland.
8. Lastly, despite being hard work, outreach anywhere is fun.

Quotes from Jersey

Secondary feedback
"This is a huge thank you from De La Salle. It has been wonderful to be involved in Science Week. The Year 12 biologists had two great sessions (Lungs and Heart). The level was pitched just right and it was a fantastic revision for them before their AS exams. It also gave them confidence and gave them the opportunity to see a couple of pieces of equipment that we cannot use in school.
The lecture demonstration, A Pollutant's Tale, was absolutely brilliant. It was aimed perfectly for our Year 8 students who came away saying it was 'awesome'. Science doesn't have to be dry and boring (my lessons being the exception, you understand!)." **Head of Science 11-18 Boys School**

Primary Feedback
"The assembly was simply awesome. I had some concerns as to the suitability for the very young ones but these proved to be totally misplaced. They sat there fascinated with their eyes getting wider and wider. One of the most pleasing things was to hear the children at the end of the day rushing out to their parents to tell them about their fantastic assembly. Please bring them back again!" **Deputy Head of a Primary School**

Education Department Feedback
"The week exceeded all our expectations and the feedback from both staff and students has been excellent. The only complaints that I have received are from schools that did not take part and are now wishing that they had! The aim of the week had been to raise the aspirations of students and excite them about science. There is no doubt that this aim has been met and we hope that we will be able to maintain and develop our links with Bristol in order to continue this work."
Andy Gibbs Head of Careers & Work Related Learning, Education, Sport and Culture, Jersey

Sustainability
Whilst the event was subsidised by the combined CETLs in the payment of the two academics and technician involved, the majority of the costs for transport, consumables, accommodation and subsistence were met by the Jersey Education Authority. The cost, for Jersey, was less than £2.00 per student engaged.

Other Mobile Laboratories
Within the UK there are three mobile physics laboratories operating attending schools, science festivals and other events, the 'Lab in a Lorry'[8] project was created in 2004 by the Institute of Physics (IOP) and the Schlumberger Foundation initially as a three year programme. These large articulated vehicles utilise trained volunteers who are physicists or engineers to work with students. The three physics experiments that the lorry carries are designed to inspire Key Stage 3 (KS3) students (11 -14 year olds) and also aim to make 'science careers more attractive' to youngsters. The free of charge Lab in a Lorry visits were created 'because of our concerns about the long-term supply of scientists and engineers in the UK & Ireland.'

The approach from the Bristol CETL's use of a mobile lab in bulk outreach differs from the IOP's in several areas:
- Only Bristol University staff and postgraduates are used.
- The mobile teaching unit is not purpose built for schools outreach.
- The chemists make use of the vehicle to carry equipment that is then used in school classrooms and laboratories thus engaging many more students per visit.
- The program of activities for the MTU encompasses KS2-4 and Post 16 not just KS3.
- Bristol does not have staffing solely for this project.
- There is a charge towards the cost of the events.

Where there is similarity
- All the relevant pieces of kit and materials are taken into the school so there is no reliance on the venue.
- The mobile teaching unit does provide additional space within a school for science activity.
- The use of practicing scientists in promoting science.
- The underlying premise is that science is best learnt by doing.

The use of mobile laboratories is not just limited to the UK. For example In the United States there are 12 mobile labs in nine states visiting their local schools. Theses are mainly delivering bioscience practical workshops[9]. Amongst these are Boston University School of Medicine's 'MobileLab'.

What Can Be Learnt From This Experience?
In previous papers we have discussed the advantages of the School Teacher Fellow concept in undergraduate teaching and outreach[1,2] and the training and advantages gained by postgraduates through outreach[3]. In addition to these continued benefits we note the following:

1. Working with the Local Education Authority representatives cut down on a lot of the preparation paperwork and logistical problems. The Jersey team organised the scheduling which not only involved the host schools but also the timetable for neighbouring schools to visit the host schools. The provision of a central 'stores' (an appropriated office) allowed some technician space, a store for the liquid nitrogen and carbon dioxide cylinders (for making dry ice) and made the 're-technicianing' of all

the outreach kits very easy. The use of a department van also aided the delivery of the primary kits to schools. The department dealt with the logistics and special permits needed to get the MTU onto the Island.

2. The decision to have an additional postgraduate to 'ride shotgun' was very useful. He was not only available for transportation, local purchasing and on-the-spot technical assistance but was also available to stand in at short notice when a flight bringing in a scheduled replacement postgraduate chemist and additional academic was cancelled.
3. This form of condensed outreach is a very powerful method for interacting with large numbers of remote students in such a short time and at a low per capita cost. In Malta a much smaller team of two academics went out for one week and, although the outreach was very well received, a larger team would have been more effective. Here the target audience was only KS4 science and Post 16 chemistry students. Altogether over 1100 students with 100 teachers from 19 of the 22 church secondary schools attended nine lecture demonstrations on climate chemistry. A separate Continual Professional Development (CPD) evening session on climate change for science and geography teachers was also arranged. The reason for lower numbers of students was the size of the venues within the schools.
4. One difficulty in Malta was that we were reliant on equipment and chemicals being locally sourced. This was not ideal as even standard laboratory equipment is not so plentiful in all the schools visited. Taking the MTU with our equipment on board was certainly less stressful than having to rely on others gathering it for you.

In both Jersey and Malta this was the first time that the organisers had worked with such an outreach team for prolonged engagement. In both cases the students were eager to see a practical demonstration being applied to theory that they had or were studying in science lessons.

Unexpected Outcomes

1. The initial planning of a one day conference on leading edge science as CPD for the Island's science teachers. It is envisaged that four or five of Bristol's scientists would give presentations on their current work to reengage the scientist within the science teachers. Through previous experiences of providing CPD for members of CHeMneT, Bristol ChemLabS network of chemistry/science teachers, we know that practicing teachers like to find out what is going on in the wider world of science but have little organised opportunity to do so. Keeping up to date with their subject matter is part of most teachers' contracts although school organised CPD is generally linked with teaching issues rather than subject knowledge.
2. There is a possibility of three day chemistry summer schools for senior Jersey Science students being held at Bristol from 2009 onwards.
3. The high level of interest shown by the media in the event. This included one television appearance on a local news programme, three separate radio interviews and newspaper interest.

Summary

A well planned series of outreach engagements, organised in cooperation with an education department, can deliver a high quality, age-relevant event to large numbers of school students of all ages at low per capita cost through the use of a small, well trained team. When working with large numbers of schools it is desirable to bring in the local education authority to assist with funding, the organisation of the schools themselves, dealing with local media and for help with local logistics.

Notes:

Bristol ChemLabS stands for Bristol Chemical Laboratory Sciences

AIMS stands for Applied and Integrated Medical Sciences

Additional Information

Bristol ChemLabS outreach leaflet
www.chemlabs.bris.ac.uk/outreach/
OutreachLeafletUKWeb.pdf

For further information on Bristol ChemLabS Outreach please see:
www.chemlabs.bris.ac.uk/outreach/

For further information on AIMS Outreach please see:
www.bristol.ac.uk/cetl/aims/mobile_lab

For information on CHeMneT please see:
www.chemlabs.bris.ac.uk/outreach/chemnet

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An investigation to determine the impact of concept mapping on learning in an undergraduate physics course

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Abstract
In recent years extensive research has been carried out to evaluate and highlight the declining number of graduates from science related courses. Following this, several initiatives have been designed and implemented throughout the Republic of Ireland to combat the problem of low retention rates in undergraduate science courses and to introduce the use of more effective instructional methodologies that promote the active role of the learner while also encouraging the facilitative role of the teacher. This paper examines Concept Mapping, one such initiative that has been implemented in the University of Limerick over the last two years. The research presented here is part of a large project that aims to explore and evaluate the potential of Concept Mapping as an educational tool in physics education. This paper, however, sets out to specifically answer the following research question: What impact, if any, did Concept Mapping have on four particular aspects of physics learning? The paper examines the effect Concept Mapping had on understanding theory, identifying physics concepts, linking prior and new knowledge and, finally, problem solving.

Background
Overall figures on student completion of university courses in Ireland suggest that an average of 83.2% of students complete the university course on which they originally enrol[1]. A study on completion[2] indicates that student completion rates are higher in Ireland than in other European countries. However, within certain areas of study the retention rates decrease. Approximately one-fifth of Science (22.2%) and Engineering (19.6%) students do not complete their courses in Ireland.

Recent research in physics education has recognised the importance of conceptual change in facilitating meaningful learning[3, 4]. In tertiary education all science students must study physics as a core subject in their first year. Therefore students who have not specifically enrolled within a physics course will study physics for only one year thus having very little experience with the subject. A majority of these students, identified as non-physics majors, will have not studied physics in secondary level education and as a result are unable to link new to existing knowledge thus preventing the occurrence of conceptual change.

Assessing understanding requires careful observation and thorough analysis. A student's ability to recite definitions of concepts is of limited value as an indicator of conceptual understanding[5]. Definitions should at least be accompanied by examples. To obtain information on the quality of conceptual change taking place within a classroom further questions must be asked and new instruments need to be introduced.

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Research Approach
In order to provide support to university students having difficulty in their course several learning support initiatives have been implemented within universities and post-secondary level institutions. In the past research focused on the activity of the teacher. However it is now increasingly recognised that student activity is central in determining what is learned. It was with this in mind that Concept Mapping was introduced in the University of Limerick.

Concept Mapping is an instructional tool introduced in the early 1970's by Novak and his research team, for the improvement of teaching and meaningful learning[6]. The tool involves students representing their understanding of scientific concepts in a graphical nature whereby concepts are connected creating a hierarchical, branching structure. The underlying technique involved is to tie new knowledge to relevant concepts and propositions already possessed[7] as it is only when we succeed in relating new information to old knowledge that we are able to understand and remember it[8]. Concept maps have been defined as two-dimensional, hierarchical, node-linked diagrams that depict

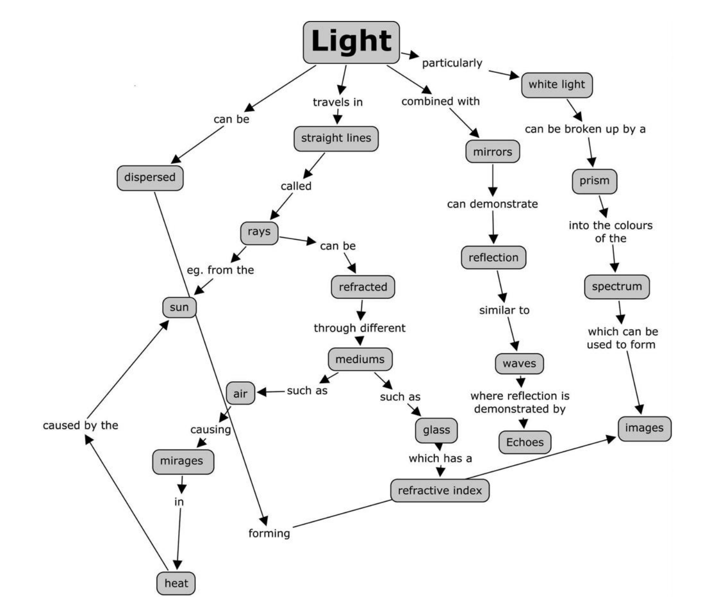

Fig 1 (a): Sample student concept map

verbal, conceptual, or declarative knowledge in succinct visual or graphic forms[9, 10]. The maps provide a representation of knowledge and hence can be used to infer accuracy and depth of knowledge. In order to be effective, instructional concept maps should contain enough important concepts to characterise the subjects that are being represented[11].

The maps have several components that as a whole represent the student's knowledge on a specific topic. The fundamental component of every concept map is the concept (node). Concepts are defined as "perceived regularities in objects or events that are designated by a sign or symbol"[12]. Concepts are generally isolated by circles and connected with lines (linking lines). These lines are labelled with "linking phrases", which describe the relationship between the two connected terms. The smallest unit of meaning in the map must contain two concepts and a linking phrase which is then identified as a "proposition". The process of constructing a concept map is a powerful learning strategy that forces the learner to actively think about the relationship between the terms. This makes Concept Mapping especially suited to studying science for the learner who perceives science as simply memorising facts[13].

Methodology

The selected first year undergraduate physics module, Sound and Light defined the context of this investigation. The module includes aspects of simple harmonic motion, sound and light waves and physical and geometrical optics. The cohort of students (N = 84) covered a wide variety of abilities from those from two courses: biological science education and physical science education. The students' timetable for this module consisted of two one-hour lecture sessions, one two-hour lab session and one one-hour tutorial each week.

Training was provided at the beginning of the study to enable students to understand clearly the method of constructing concept maps. The training session was intensive and lasted for fifty minutes. During the training session students got the opportunity to construct maps both in groups and individually. Students then discussed any problems or issues they had with the Concept Mapping tool before the study was commenced and any data gathered. Throughout the period of study students were asked to construct individual maps specific to the module being taught. These Concept Maps also formed part of the delivery of the module where they were used as 'advanced organisers'[11], allowing the students to identify the relationship between concepts and providing a reference from the beginning of study.

Each student constructed three maps throughout the duration of the 12-week study, a sample of which can be seen in Figures 1(a), 1(b) and 1(c). The level of direction provided varied with the three maps. Direction for the first map consisted of instructions and guidelines to help construct the map and contained a list of seed terms to assist the students in constructing the maps. The second map contained instructions and guidelines with no concepts while the third map contained only the instructions. For each map the

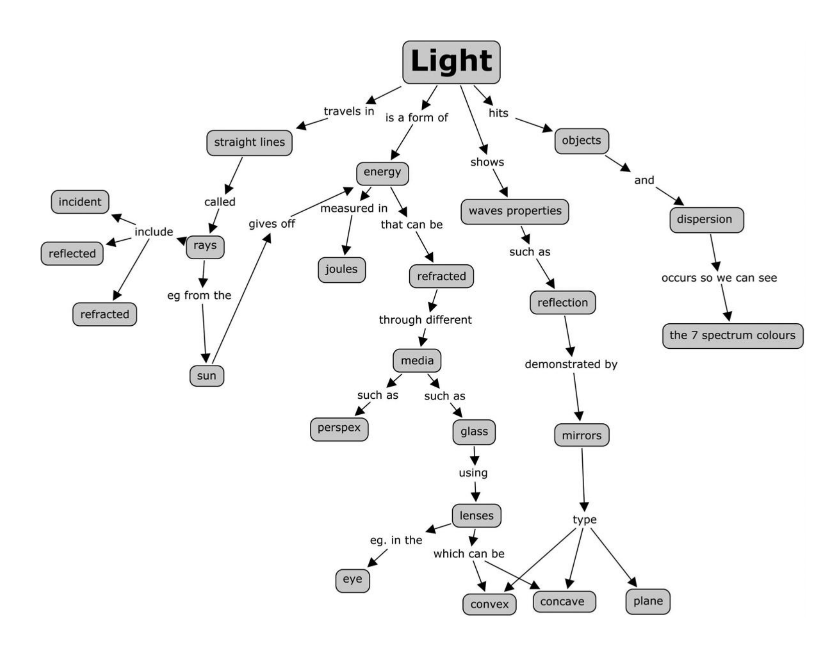

Fig 1 (b): Sample student concept map

students were encouraged to first make a list of all concepts that they believed were important in the topic of light, and then to link these concepts in the form of a map. The students were given the same key concept for all three maps to examine the development of their knowledge over the 12 weeks. The post-questionnaires were self-administered in week 11 after the students had constructed all three maps.

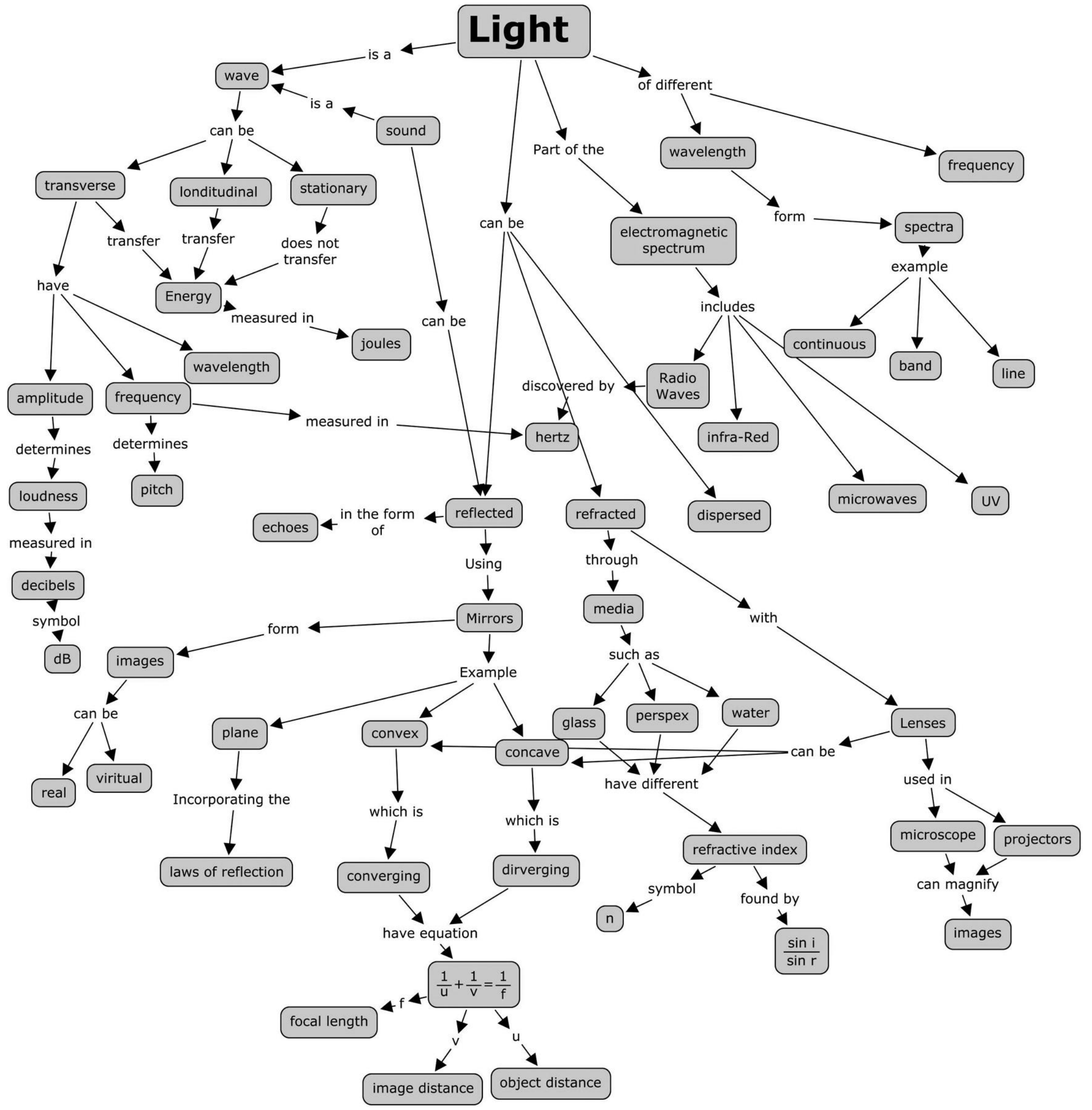

Fig 1 (c): Sample student concept map

Evaluation

Analysis of the concept maps was carried out throughout the study and students were given written feedback after the construction of the first map and oral feedback after the second. The written feedback consisted of comments indicating the overall level of the map and highlighting areas on which the students should concentrate, for example the use of linking phrases. The maps were corrected against an expert 'criterion' map which was constructed by the author. All propositions included in the criterion map were specific to the course outline. A 3-point scoring system was developed where one point was attributed to a correct proposition, a half mark for partially correct propositions and zero for a scientifically incorrect one.

Following the 12-week experience with Concept Mapping students rated the effect the tool had on their learning of physics. For the purpose of this study the results focus on four key areas. Students were asked to state, using a Likert Scale, whether they agreed that after their experience with Concept Mapping they were able to:

- Understand the theory more easily
- Identify physics concepts
- Link prior and new knowledge
- Answers problems more easily.

To determine if the Concept Mapping experience had an effect on students' problem solving ability, the final semester exam grades were analysed and compared against the results of the students' previous physics module, PH4101 Mechanics and Heat. The lecturer for both modules was the same, however the teaching assistant allocated for the timetabled tutorials was not.

	Strongly Agree (%)	Agree (%)	Unsure (%)	Disagree (%)	Strongly Dis-agree (%)
Understand the theory more easily	25.4	52.4	12.7	9.5	0
Identify physics concepts	19.0	58.7	17.5	4.8	0
Link prior to new concepts	55.6	30.2	6.3	7.9	0
Answer problems more easily	12.7	44.4	23.8	17.5	1.6

Table1: Statistical analysis of student questionnaires

Results

Following statistical analysis of the student questionnaires the data suggests that the Concept Mapping experience improved the students' learning of physics. (Table 1). Over 50% of all students agreed or strongly agreed that by constructing concept maps they were better able to understand the theory more easily, identify physics concepts, link prior and new knowledge and answer problems more easily. In spite of this, a number of students did 'strongly disagree' with the statement that Concept Mapping had a positive effect on answering problems: 1.6% of students strongly disagreed that Concept Mapping allowed them to answer problems more easily with a further 17.5% disagreeing with the statement. The students felt that although they had a better understanding of the theory they found it difficult to manipulate the equations and solve problems. However, when the students' exam results were analysed for both their previous and current physics module there was an improvement of 11% in the number of students scoring higher than a C grade (Table 2).

Semester	A (%)	B (%)	C (%)	D (%)	F (%)	NG (%)
SEM 1 Mechanics and Heat PH4101	3.3	14.6	47.2	16.8	17.9	0
SEM 2* Light and Sound PH4202	3.5	29.7	42.8	10.7	10.7	2.3

Table 2: Students grades in end of semester exams for the module they completed using concept maps and the previous module taken earlier that year (Note: NG implies No Grade, signifying the student did not sit the exam)*

The key point in this study is that over 85% of students felt that the Concept Mapping tool facilitated the linking of prior to new knowledge. This is imperative for meaningful learning to occur. It is only when students can integrate new science concepts with existing concepts that an improvement in conceptual understanding can take place.

The questionnaire also set out to evaluate students' perceptions regarding Concept Mapping. The students' responses were extremely positive regarding the effect the tool had on their attitude towards physics, with 61.9% agreeing that this improved after their experience with Concept Mapping. Students were then asked if they felt that Concept Mapping was beneficial in a physics classroom. The response to this question was very consistent, with a large proportion of students acknowledging that they felt it is a very valuable revision and study aid. Sample responses include:

> *"Yes it makes you think about everything you know on a certain topic. It encourages people to generate words first and then connect them"*
> *"Yes it summarises what you have learnt and is a form of revision exercise testing your understanding of a topic"*
> *"Yes it allows you to relax and think about the topic rather than rushing to answer a question".*

Conclusions and Implications for Future Directions
Data from this study indicates that concept maps can be an effective tool for improving the learning of physics. Summarising the quantitative and qualitative research we can conclude that concept maps help students integrate prior and new knowledge, understand theory more easily, identify physics concepts and answer problems more easily. It may also be argued that students' grades in the end of semester exams improved following the incorporation of Concept Mapping into the modules as an instructional method.

Concept Mapping is an interesting instructional tool that facilitates meaningful learning and stimulates critical thinking. It assists students in constructing their own understanding and allows them to represent their level of knowledge throughout their course of study. This paper's preliminary findings suggest that the Concept Mapping method employed is effective in providing suitable learning opportunities to undergraduate physics students.

Training was provided at the beginning of the study to enable students to understand clearly the method of constructing concept maps.

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Transitions to HE: CBL for non-traditional students

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For most students, their motivation, or lack of motivation in some cases, is likely to be a based on a complex mix of personal factors, as well as other factors such as curriculum design.

Abstract
The aim of this paper is to describe the development of contextual based learning resources appropriate to Science Foundation students at the University of Huddersfield. In developing new resources the authors consulted with key stakeholders in the science community. A world class glass manufacturer and an industrially focused research and development unit based in the University of Huddersfield provided input into how industry based scenarios could be developed for use in the curriculum. Teachers from one of the country's leading sixth form colleges provided examples of effective context based learning in an FE environment. This paper charts how an effective teaching and learning strategy has been tailored for use with Science Foundation students. It provides key examples of how context based learning (CBL) has been adapted for use with students of mixed abilities and backgrounds. The paper also highlights some of the problems encountered in developing appropriate resources and presents initial findings of the impact on students.

Introduction
Research into learning styles at the University of Huddersfield's School of Applied Sciences was the catalyst for this project. The School offers a Science Foundation year for those who lack the necessary qualifications, skills or experience to enrol on first year science or science related undergraduate programmes. This year zero option is a popular choice for mature students returning to education and younger students who may have recently underperformed at A-level. Intuitively, an understanding of learning styles may offer one way of making the transition to HE smoother for these non-traditional students. However, a recent influential research report has all but dismissed the use of learning styles questionnaires citing concerns about both reliability and validity[1]. While there is still plenty of debate concerning how or whether learning styles questionnaires should be used, the report recommend that lecturers should consider the learning strategies employed by their students. Much of the research in this field has led to the development of a framework capturing the personal dimension behind student learning[2]. The dichotomy here is that of 'intrinsic' motivation where students have an inherent interest in a subject, and 'extrinsic' motivation where the value placed on study is related to the qualification it confers or the employment it secures[3]. For most students, their motivation, or lack of motivation in some cases, is likely to be a based on a complex mix of personal factors, as well as other factors such as curriculum design[4]. As Science Foundation represents a potential first step on a longer programme of university study, these issues are highly relevant. In the past, successful Science Foundation students have gone on to study Chemistry, Forensic Sciences, Biomedical Sciences, Pharmacy, Midwifery, Podiatry, Radiography and Nutrition and Health. The connections between Science Foundation modules such as chemistry, biology and physics, and students' longer term study and career aspirations are not always immediately obvious. Nevertheless, each student must successfully complete each module if they are to progress. Initial research with previous cohorts of Science Foundation students has shown that some can have difficulty engaging with a topic, especially where they may only require a 40% pass mark or where that topic is not necessarily relevant to their future education or career. One way of addressing this might be through the development of bespoke context-based learning (CBL) sessions. This is a topic that has been covered in *New Directions* before[5] but discussions of its use and value often focus on undergraduate students. The aim of this short paper is to report on the first steps in the development of CBL sessions for a chemistry module. In the longer term it is hoped that this work will contribute to the research in the areas of enrolment choice in the sciences[6] and how mature students contend with the transition process[7]. The immediate challenge, however, was to develop CBL sessions that were appropriate for this level of study, without compromising existing budgets, resources and contact time.

Developing Resources
Since 2006, Pilkington has supported the University in events such as the RSC's outreach initiative 'Chemistry at Work' and has also provided educational materials for public lectures on materials science. It was hoped that this relationship might lead to the development of CBL sessions that could help students understand the science of glass manufacture. Initial meetings were encouraging, but factors, such as the cost of materials and equipment, limited the portability of the ideas generated. This experience highlighted some of the difficulties inherent in producing laboratory-based CBL sessions, but the input was useful in providing ideas and suggestions for laboratory sessions and projects for undergraduate chemistry students. More relevant industrial support and advice came from Innovative Physical Organic Solutions (IPOS), a chemical research consultancy service based at the University. IPOS specialises in analytical chemistry and they suggested the use of UV and IR spectrometers in a forensic based scenario for the first session. These instruments have the advantage of being effective and easy to use, as well as providing data instantaneously. Crucially this meant that experiments could be conducted and results could be produced within the one hour timetabled for each session. The second session was based on the contextualisation of polymers in the film and TV industry. A series of short experiments were devised for the session, with varying parameters for students to explore, showing how the materials could be used in the industry.

In terms of the delivery of the sessions, help and advice came from Greenhead College, a 'nationally acclaimed' local sixth form college. Here, CBL has been used successfully for a numbers of years, in the form of the Salter's Chemistry course. Salter's courses are built around contextualised science, which emphasises industrial and real-life applications of chemistry[8] and as part of the development process, a number of classes were observed. The teachers at Greenhead felt that the Salter's Chemistry pathway was a way of obtaining a more rounded science qualification and the students recognised both its complexity and value when compared to traditional A-level teaching. Both teachers and students enjoyed these sessions and there were high levels of activity and interaction throughout. Further discussions with staff suggested that this style of teaching offered an appropriate model that could be transferred to the Science Foundation laboratory sessions. Staff at the college suggested interactive materials and advice on teaching techniques. However, this was not just a question of simply transposing Salter's Chemistry on to the Science Foundation course. With the help of Dave Newton, a Chemistry teacher at Greenhead, resources were developed and adapted for use at the University. These adaptations had to take into account the plethora of external commitments that some students face and the impact this has on attendance. As a result one of the major changes was to produce shorter stand alone scenarios, rather than longer storyboards delivered over the course of an academic year. As a starting point two sessions were developed and delivered with a view to increasing the number of sessions in the longer-term.


Figure 1: Science Foundation students develop their practical skills


Figure 2: Student engagement and collaboration in the laboratory

Delivering the sessions and assessing their impact
The structure of the new sessions included a problem or a question that might be faced by an applied scientist but delivered in a framework that was provided by Greenhead. This meant that the real world importance of scientific manufacture or application could be highlighted to the

students and they could carry out a series of laboratory experiments to develop their own understanding. These sessions were designed with Science Foundation students in mind many of whom lack key laboratory skills. The information portrayed in the laboratory sessions was fully contextualised, and directly linked to the week's lecture topic. After the laboratory session, students were also asked to carry out brief independent research and subsequently answer questions to consolidate their learning and to build further on their understanding.

A selection of students were given the opportunity to participate in laboratory based sessions which replaced the traditional tutorial session held in a classroom. All students received the same two lectures in that week; however for half the Science Foundation cohort the usual question sheet based tutorial was replaced with a practical laboratory session. In total, three groups comprising 42 students in total took part in both sessions. Groups were chosen on their longer term career aspirations. The first group comprised students predominantly wanting to progress onto a pharmaceutical sciences degree. The second comprised a high number of students hoping to study pharmacy and who were achieving higher than average grades in chemistry. The final group consisted of students hoping to pursue the vocational health degrees such as midwifery, podiatry, dietetics, nutrition and health. In choosing the groups to take part, other factors, such as the availability of resources and laboratories, and timetabling, also played a part. Nevertheless, it was hoped that the differences among these groups in terms of the longer term relevance of chemistry to their aspirations would allow a test of the impact of this teaching methodology across a wider audience.

One student talked of a 'buzz' among the group as they left the (sessions) while another expressed concern that his group had missed out on the opportunity to participate.

Preliminary Conclusions
Early anecdotal evidence strongly suggested that students enjoyed participating in these sessions. One student talked of a 'buzz' among the group as they left the (sessions) while another expressed concern that his group had missed out on the opportunity to participate. While the primary purpose of this project was to explore whether CBL could be adapted for Science Foundation, given existing logistical and resource limitations, the authors were keen to analyse this evidence in more detail. Questionnaires were distributed to all 42 students who had taken part in either one or both of the new sessions. Of those, 21 were returned ranging from those who had longer term study and career aspirations in chemistry, to those who had little experience or no longer term interest in the subject. Given this relatively small sample, it is not possible to extrapolate any firm conclusions about the impact on the sessions on chemists and non-chemists. Nevertheless, the findings below provide important indicative data about how the sessions were received by the students, which will be useful for longer term curriculum development.

The feedback was encouraging. 86% of respondents agreed or strongly agreed that the CBL sessions were 'interesting' compared to 76% for existing tutorials delivered by the same tutor. Students commented that the CBL format was 'excellent', 'interesting' and one stated that she 'absolutely loved [it]'. In other areas too, student responses to the sessions proved to be positive. Participants were asked to comment on whether CBL provided more opportunity than normal tutorials to work collaboratively, to share ideas and to develop numeracy, practical and analytical skills. Across all these areas positive responses were received. For example, 90% of students agreed or strongly agreed that CBL offered more opportunity to develop practical skills. These results are encouraging and seem to suggest more engagement and participation. Figure 1 shows the development of practical skills which would not be possible in the normal classroom environment. The survey results, and photographs, such as figure 2, are encouraging and seem to suggest more engagement and participation. However, other factors played a part. Some students drew a link between CBL and information provided in the lecture. One student wrote that CBL 'brought elements being covered in the lectures to life' while another felt that the sessions were better because 'you could actually see polymers and how they reacted'. These comments are significant because they highlight the importance of consistency or alignment across different elements of the curriculum[9]. For other students it is clear that CBL was preferable to existing tutorial methods because it was 'enjoyable, not boring.' Similarly, another student commented that 'the CBL session was more enjoyable….than classroom stuff'. Despite these comments, other students placed value on the traditional tutorials because they provided a relaxed environment to ask questions and discuss problems. One commented that 'they are useful and you can speak up to receive help with difficult areas'.

From the outset, these CBL sessions represented a starting point. One of the main criteria for the success of this project was the production of re-usable resources within a limited budget. This has been achieved with input from partners in industry and FE. While discussions with Pilkington did not provide anything concrete for this particular group of students, IPOS were able to provide some focus to the early stages of this project. Similarly, building a relationship with colleagues in the FE sector helped put these sessions into context. Overall, the responses of the students who took part in these sessions were positive, and in part, this was because of their views about existing methods of teaching in tutorials. Science Foundation students see a value in existing teaching and learning methods even if they are 'boring' or not as interesting as the new CBL sessions. This strongly suggests that for this group of students the introduction of CBL sessions has to be part of a blended approach to curriculum delivery.

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One of the main criteria for the success of this project was the production of re-usable resources within a limited budget. This has been achieved with input from partners in industry and FE.

Contribute to the next issue!

If you would like to contribute to the next issue in the first instance please send a short summary/ abstract, by 1st March 2009, to the editor...

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The deadline for full articles is 1st June 2009.

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

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

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

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

We are seeking the following as contributions…

Reviews of topics in physical sciences education and educational research

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

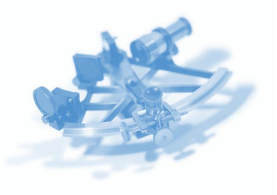
Communications

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

Initiatives

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

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



Style guide for contributors

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

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

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

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

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

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

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

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

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

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

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