[W1] The physics and chemistry boxes

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Many Physical Science departments are struggling to attract sufficient numbers of students and virtually all of us are also unhappy that the more able students are not choosing science for their higher and further education. This has led to the complete closure of a number of departments; a merger with cognate disciplines for some, or relegation to a 'service teaching' role for others. Despite this dramatic fall in capacity, there is still a shortfall that is a major cause of concern for all but a handful of institutions.

HOW CAN WE PERSUADE MORE SCHOOL PUPILS TO CONTINUE WITH THE PHYSICAL SCIENCES?

Surveys show that Physics students are most influenced in their choice of planned honours school by their enjoyment of the subject (87%), success in examinations (74%) and their teachers (27%). Demonstrations (9%), parents (9%), the media (4%), and their peer group (3%) were much less important. The message is clear (Norman Reid in 'Getting Started in Pedagogical Research in the Physical Sciences', LTSN Physical Sciences Practice Guide) –

> 'School experience is the dominant factor - the quality of the school syllabus and the quality of the teachers is critical.
>
> The principal area where we may have an influence, as academics, is in the perception of career opportunities.'

Nick Jagger, in a substantial document (The Right Chemistry: The choice of chemistry courses and careers, Institute for Employment Studies) re-iterates and expands on this. Some of his many points, aimed at University teachers are – Build on the public's positive attitudes to the products of chemistry. Re-claim topics such as nanotechnology for our own. Encourage teachers to use appropriate materials. Understand students' career aspirations and publicise remuneration. Develop new curricula, and be aware of changes in education. Cooperate, not compete, when responding to funding problems.

Averil Macdonald provides much valuable advice in' 'Outreach – A Guide to Working with Schools and Colleges' also available on the Centre's website. A few selected extracts are,

Produce resources for use in school
Posters, worksheets, books, homework activities, question sheets, data analysis exercises, web resources, CDROMs, datasheets, formula sheets or periodic tables etc. Despite the modern myth that people only value what they pay for, teachers love freebies. However, above all, teachers value directly useful material and will put it on the wall or use it in class.

Produce resources for use in 14-16 classes (GCSE and Standard Grade)
Teaching Resources which directly target elements of the 14 - 16 specifications will be of great use to teachers if they introduce some

cutting edge science that does not feature in text books and to which teachers may not have easy access. Supplying the material on a CDROM allows the school to network the materials.

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

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

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

THE PHYSICS BOX

The Basic Challenge

How can we hope to match a school oral presentation against all of the whizzo 3D graphics in modern arcade games and compete with the specialist, creative talents now being unleashed on a multitude of TV science programmes? It seems to me that a plausible solution must incorporate a number of factors:

- We must engage the students with humour and present unusual applications of physical effects (including perhaps magic tricks), and give them simple mathematical quizzes and physical science challenges for group discussion i.e. make it fun.

- We must surprise them with reliable but spectacular effects, that they most likely have not seen or heard e.g. the frisky ping-pong ball, the latest magnetic levitation device and radio emissions from Jupiter. But also we could challenge some 'common-sense' assumptions they are likely to make and discuss the bases of pseudo-science.

- We must boost their confidence by defining simple, quick, construction projects like building a crystal set and an electric motor/dynamo, or creating their own Doppler Effect/Sonic Boom calculating device.

- We must personalise science by telling (true) stories 'warts and all' about great scientists and amateur inventors; also to include some cases of well documented scientific blunders and showing the limitations to our current knowledge.

- We must try to make interconnections across the whole of physics and into other scientific disciplines. Take some everyday effects from the home and interpret them OR modify normal conditions in a particular circumstance and show them something that then defies a simple explanation.

- We must search for the 'wow factor' or eureka moment – what natural phenomena are really going to blow their minds? For myself, the real eureka moment was when I was a young teenager mucking about with radios and basic electronics. One day I heard 'whistlers' in Nottinghamshire when I accidentally connected a substantial earth wire to the input of an audio amplifier. I did not know what they were at the time but later, after my first degree at Imperial, I almost joined a research group based at the University of Southampton who were doing whistler research in the Orkneys.

Mathematical Limitations

The mathematics introduced should not be too difficult, but quite a lot can be done with the likes of simple formulae such as a=b/c even if we do totally disregard, say, exponentials and calculus. Remember that we are trying to get at the 'middle-of-the-roaders' who may be persuaded to study more science at AS and A levels and then hopefully consider university science courses! It would be left to the discretion of the presenter to show the student how higher level mathematics could make the explanations more complete. We would hope that our approach is consistent with the Aim Higher Initiative – we do not see the Powerpoint exemplars that will be defined in the package as dumbing-down in any sense because they are starting points for further exploration if the student's interest is aroused.

Physics Box Contents

The 'Physics Box' will consist of;

- Around 15 Exemplar Case Studies (PowerPoint presentations) on topics such as Frames of Reference and Relativity, Scale Size and Defying Gravity, Balls in Flight, Magic Tricks and Optical Illusions, The Radio Universe etc.
- Over 60 quiz/challenges on individual PowerPoint presentation slides to stimulate discussion – these will be logical, mathematical and scientific puzzles.
- Over two hundreds individual Word files containing suitable newspaper articles, short scientific texts, images, sound snippets (.WAV files), video clips, cartoons and background text relevant to GCSE level curricula.
- List of websites which are excellent resources for on-line teaching, books and articles for further reading, sources of materials for demonstrations.

Conclusion

The Physics Box is not meant to be a rigidly defined and static resource – rather it should be seen as a starting point for creating more such snippets of information or 'factoids'. These 'factoids', which can be added to the speaker's specific research activities or special interests, should help create a comfortable Powerpoint structure for each academic speaker. It presupposes that the speakers who use this resource will also have at their disposal a number of hardware components in order to demonstrate a particular effect or to persuade the students to be creative and build their own devices. Edward de Bono claimed, rather provocatively, in the Sunday Times Supplement recently (February 27th 2005) that: '*Secondary schools waste two-thirds of the student talent and our universities sterilise the remaining third'!* You may think that this is a somewhat harsh assessment of our educational system but maybe there is an element of truth. You would think that, if everything in the garden were truly rosy, we should be able to produce enough graduate physics teachers to complete the 'educational circle' – physics graduates who want to inspire the next generation of secondary school students into the beauty of our subject? I hope that this resource will help enliven some school presentations and generate enthusiasm amongst the students.

Table 1: The Presentations – Contents

<table>
<tr><th>Cosmetics</th><th rowspan="1">Food</th><th>Medicines</th></tr>
<tr>
<td>History
Skin
Aging
Colouring
Moisturisers
Deodorants
Sunlight
Hair
Colouring
‘Perming’
Combing
Perfume
Lipsticks
Toothpaste</td>
<td rowspan="3">Vitamins
Minerals
Additives
Energy
Dieting
Proteins
Carbohydrates
Bread
Fats
Prostaglandins
Cholesterol
Margarine
Chocolate
Cooking
Smells
Drinks
Caffeine
Fruit Juices
Alcohol
Beer
Wine
Water
‘Specialities’
Natural Food
Organic Food
Junk Food
Chirality</td>
<td rowspan="3">How medicines work
Enzymes
Receptors
History
Statistics
Drug synthesis
Design strategies
Examples
Antibacterials
Analgesics
Amphetamines
Tranquilisers
Antihistamines
Hormones
Hallucinogens
Homeopathics
Viagra, the Pill
Abuse</td>
</tr>
<tr><th>Semiconductors</th></tr>
<tr><td>Bonding in metals, insulators, and semiconductors
Impurities and Dopants
n-type and p-type
Zone refining
Chip fabrication
Nanotechnology</td></tr>
</table>

THE CHEMISTRY BOX

In a partial attempt to address the issues covered in the introduction, The Chemistry Box consists of a series of presentations intended to provide lecturers visiting schools with some background material that explains the contributions made by chemists to modern society. It is hoped that these talks will be stimulating and excite pupils into taking the subject further at school and beyond and the contents of these lectures are aimed at helping this process. Additionally, the DVDROM contains valuable computer assisted learning material, chemical tools (such as structure drawing and a chemical calculator) and a substantial collection of videos.

The presentations are devised as complete lectures and may be used as such. They often contain animations and transitions that it is hoped will appeal to the target audience and thus these may be a bit irritating to some presenters. Notwithstanding teachers and academics are encouraged to modify them to suit their own purposes. This might involve changing the contents, using just a few slides in their own presentations or creating new presentations by amalgamating sections from several. For this reason, the files are not copy-protected in any way.

Table 2: Other Materials

Computer assisted learning modules: The Chemistry Tutor II

Chiral molecules	Diastereomers	Conformations
Projections	Carbonyl compounds	Aromatic substitution
Alkenes and alkynes	Alkyl halides	
Introduction to spectroscopy	NMR spectroscopy	
Atomic structure	Descriptive trends in the Periodic Table	
Numerical trends in the Periodic Table		
VSEPR theory		
Molecular energy storage	Elementary radioactivity	
Gaseous equilibrium thermodynamics		

Tools

Chime: A tool for manipulating 3D structures on the web, licensed from MDL.
Chemical Calculator
Mass Calculator
IsisDraw: A chemical drawing program licensed from MDL.

Experiments: A simple Word document containing over 60 laboratory experiments suitable for schools.

Chemical Games

Quizzes: A series of numerical quizzes on algebra, particles and radiation, spectroscopy, thermochemistry and volumetric titrations

Simulations: Programs on kinetics, moles, the Maxwell equation, particles and waves, rotations, simple vibrations and spectroscopy

Videos: These have been generously made freely available to education by the authors.

EMOL Films (samples of videos from Educational Media On-Line)

The Briggs-Rauscher Reaction	Convection in Liquids
The Creation and Destruction of Foam	The Zhabotinsky Reaction
The Crystallisation of Polypropylene	
Oscillations in melamine crystal lattices	
Three animations of vibrating molecules	

Films from Sheffield University:

An Introduction to IR	*An Introduction to NMR*
Common Sense in the Laboratory	*Understanding Materials*
An Introduction to Organic Polymer Chemistry	

Liquid Air by Liverpool University.
Oxidation by Liverpool University.
Salt by Liverpool University.
Vibration Modes: Animations of vibration.
IR.avi, MS.avi, NMR.avi: Three videos on infra-red, NMR and Mass spectrometry accompanying the ‘Spectroscopy’ simulation program.

Waking Without Chemistry

The backbone of the series, entitled ‘Waking without Chemistry’ is a light-hearted look at what a school pupil might encounter upon awakening and preparing for school should there be no such thing as a chemical industry. It contains lots of sound effects, videos and fancy transitions plus a little humour. It is the only one designed to be used ‘as is’ although, in keeping with the philosophy of the whole series, no restrictions are placed on any desired modifications. It is perhaps the best one to give to schools for their own use since it can provide much stimulus for future debate and classroom explorations and contains very little chemistry that requires interpretation (the lecture on medicine, in particular, may need the lecturer to deal with complex nomenclature, formulae and some concepts).

‘Waking without Chemistry’ deals with topics such as semiconductors, electricity and lighting, polymers, electrochemistry, medicine, cosmetics, food, transport and clothing. The final part suggests a few topics that might assume importance in the future and talks about the most recent Nobel prizes in chemistry, hydrogen fuel, degradable polymers and so on.

Each item introduced by this presentation is capable of forming a whole series of lectures in its own right and some of these have been prepared and placed on the disk. Their contents are shown on the previous page.

Statistics and Studies – Contents

There are several presentations containing statistics that could be useful on a school visit plus some interesting reports. These are also put into presentation form for convenience. The figures are as up-to-date as possible at the time of preparation (Spring 2005) but, since government and other public bodies are notoriously slow, they may refer to surprisingly early dates. In a few cases, the original reports are included.

Attitudes: Public perceptions of Science and Scientists. Surveys in 2000 and 2005.

Science Careers: Typical career opportunities and remuneration.

University Admissions: Some fascinating details of admission and success rates.

[W2] Engaging with the ethical implications of science

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INTRODUCTION

Perhaps the first question that many will ask is 'Why should we engage with the ethical implications of science?' It may be argued that as scientists our job in research is to investigate the universe and in teaching, to enable our students to understand current hypotheses and the reasons why they are held. We deal, the argument continues, in data and evidence gained by rigorous experimentation, observation and measurement - the Baconian approach to understanding the world. Ethics, i.e. the attempt to systematise questions of morals, questions of right and wrong, surely lies outside our remit.

Such a view is not, however, endorsed by the authors of the QAA benchmarking statements, which stress that students across a range of disciplines, including biological sciences, should be aware of and be able to demonstrate understanding of the ethical and social implications of advances in their subject (QAA, 2002). We believe that the reasons for this are clear; it is no longer appropriate to regard the sciences as existing in isolation. Scientific activity is part of our culture, supported by and embedded in society. That is not to say that we regard the findings of science as socially constructed, a position that we firmly reject. Nor is it to say that science is warmly embraced or even understood by the whole of society: it very clearly is not. However, science is surely accountable to the society that supports it, and that accountability includes being aware of the wider implications (see Bryant et al, 2005). In biological sciences especially, those wider implications are growing fast. Modern biological and biomedical science is giving us power to manipulate the lives of other living organisms and of other humans in ways that were undreamed of only a few years ago. Society is therefore faced with dealing with the new possibilities that arise from scientific advances. But in our view, scientists cannot opt out at this point. At the very least, they have the responsibility to communicate clearly what is possible and what is not, to make sure that the science and its possible applications are understood so that ethical considerations are rooted in reality. We would go further, and suggest that scientists should also participate in the debate itself or, as the title of this paper suggests, be able to engage with the ethical implications (see, for example, Willmott, 2004).

HOW DO WE HELP SCIENCE STUDENTS TO ENGAGE WITH THE ETHICAL IMPLICATIONS?

Inevitably, given our fields of interest, we (the authors) have most experience of ethics teaching focussed around biological and biomedical issues. As we have already stated, these are currently areas of particularly intense ethical debate. This is not to say, however, that other disciplines such as chemistry and physics are devoid of suitable topics. Indeed, a fairly cursory survey reveals the existence of a number of web-based resources already directed at these subject areas. For example, Case Western Reserve University hosts the Online Ethics Center for Engineering and Science (http://onlineethics.org) and there are other portals specifically associated with

Chemistry (e.g. http://www.istl.org/01-spring/internet.html and http://www.lib.duke.edu/chem/ethics; see also Coppola, 2000). In the realm of Physics, the cold fusion' affair and Millikan's oil-drop experiments are broadly discussed (see, for example, Thomsen, 1999, and Goldfarb and Pritchard, 2000). The Joint statement on skills training, to which all of the UK Research Councils are signatories, specifies that all research students should be able to 'demonstrate awareness of issues relating to the rights of other researchers, of research subjects, and of others who may be affected by the research, e.g. confidentiality, ethical issues, attribution, copyright, mal-practice, ownership of data and the requirements of the Data Protection Act' (see, for example, EPSRC, 2003). We have found Shamoo and Resnik (2003) to be a particularly helpful text in this regard.

Thus, ethics education is of relevance to all fields of science. It is our conviction that the methodologies outlined below, although 'road-tested' in the biosciences, are readily transferable to other subject areas, even if the specific examples are harder to identify.

Ethical theory and moral philosophy

In the end, ethics is about making decisions, decisions about what is a right or appropriate course of action. A simple statement of this kind hides all manner of complexities, including the theoretical background to ethical decision-making. It was brought home to JB some years ago that moral philosophers, like scientists, have their own language and part of that language is the description and definition of the various ways in which ethical decisions are made. JB had not heard of the terms *deontological* or *consequentialist* until he participated in a group that was writing a response to a Human Fertilisation and Embryology Authority (HFEA) consultation. However, the use of terms such as these that define different ways of making moral decisions made him realise that different people may use different systems in their ethics and that their worldview may affect the use of those ethical systems. Thus, we, in our respective universities, consider it important that students have a basic grasp of ethical theory so that first, they have insights into why they hold their views or reach their conclusions and secondly, so that they can recognise the types of argument used in debate or discussion. It is certainly not our job to try to tell our students **what** to think; however, we hope that our courses teach them **how** to think. Armed both with a good working knowledge of the science and this basic grasp of ethical theory, our students are well placed to participate usefully in the debate.

Focussing on the issues

As we have already stated, if ethics is to mean anything, it means coming to a decision. The debate is essential, but eventually a course of action must be decided on. For example, over the past two years, the HFEA has debated a number of cases in which it was desired to create *in vitro* an embryo that, if allowed to develop to full term, would be a stem cell donor for a sick older sibling (see http://www.hfea. gov.uk/PressOffice/Archive). This 'saviour sibling' scenario presents extensive oppor-tunities for ethical debate but unless that debate is aimed at reaching a conclusion, it is of no use at all to the families involved: the prospective parents need to know whether the procedure will be permitted. We therefore make extensive use of **scenarios** and **case studies** in teaching bioethics (Bryant and Baggott la Velle, 2003). In other words, we employ a form of problem-based learning. Students work on these as individuals, or in pairs or groups but the key aim is to get them to make a decision. Thus they need to decide which factors in the case study are relevant and what relative weight to give to each of those factors as they make their decision. It is very valuable to get the students to analyse their reasons for reaching their conclusion. This will give insights into the way that they as individuals make ethical decisions and may, in some groups, illustrate how different world views lead to different outcomes.

The previous point is important. Many students may assume that their culture and worldview is universal. It is very valuable that students come to realise that different worldviews may give rise to different ethical decision-making processes (e.g. deontological, based on duty to follow certain courses of action *versus* consequentialist, based on evaluating the outcome of an action) or may lead to significant factors being weighted differently (e.g. in ‘double-effect’ situations where a treatment to relieve pain may hasten death). This point can be further emphasised in **role-play** where students (or sometimes academic staff) research and present different positions within a particular ethical **debate**. One of us (JB) has been involved in role-play concerning the utilisation of rain forest in South America (see Bryant et al, 2002). Other successful role-plays, reported from the USA involve students taking the roles of the real participants in the national debate on stem cell research (Fink, 2002; Rubin, 2004). Further, role-play may be extended into full-scale **drama**, which is a very powerful tool in presenting the human emotion and tension in some current medical ethical debates. Thus one of us has been involved with the drama department in his university in producing a play, *A Present for Anna*, about saviour siblings (exstream@exeter.ac.uk).

Viewing and listening

Producing *A Present for Anna* did not directly involve biology students although it was clear that the drama students gained great benefit from the exercise. However, the play itself is a great teaching tool, involving the audiences in actually deciding whether to permit the creation of a saviour-sibling embryo, once again emphasising that real ethics is about making decisions. The play was toured to high schools and to some universities, and for the latter, supplemented the bioethics teaching that was already taking place. Other theatre companies, notably Y touring (www.ytouring.org.uk) have a strong track record for productions that illustrate dilemmas in contemporary science, including *Pig in the Middle* (about xeno-transplantation) and *Genes R Us.*

Even in the absence of a suitable play, there is vast resource of both fictional and documentary material available on **DVD and video**. For example, the film *Gattaca* portrays a world in the near future in which the genetically selected ‘Valids’ have privilege over the naturally-conceived ‘In-valids’. The film provides extensive opportunity for discussion of a range of ethical issues, including embryo selection and genetic discrimination[1]. A number of TV ‘drama-documentaries’ have also been produced, including the highly acclaimed *Born with Two Mothers* about a mix-up at an IVF clinic, which results in one woman giving birth to a different couple’s child (see Ashcroft, 2005 and Channel 4, 2005, for a consideration of some of the ethical issues which could be developed out of a screening of the programme).

The BBC science series Horizon has been accused of ‘dumbing-down’ in the recent past, yet several recent episodes have relevance for teaching about ethics. Notable amongst these are *Who’s afraid of designer babies?* (BBC, 2005) and *The dark secret of Hendrik Schön* (BBC, 2004). The latter is useful on two levels, for a discussion of nanotechnology, but also as an example of dishonesty and a lack of research integrity.

Similarly, news footage of current developments can provide pithy illustrations around which discussion can be developed. For example, one of us (CW) has developed an exercise utilising a few minutes of Channel Five news about the first application for permission to clone human embryos for therapeutic purposes. This short report lends

[1] Although, from our knowledge of high school teaching, many of our students may have seen the film as a teaching aid during their last two years at school.

itself to a discussion of the science involved in the procedure, the ethical implications of the work, and the ethical reporting of one's work to the media. This reminds us that, of course, whenever students watch a play or video, we need to encourage 'active' watching and it is sometimes helpful to produce a checklist of points to watch out for or to consider as they are viewing.

A further method that has been successful employed to help students engage with the ethical dimension of the subject involves **production of websites** on a specified ethical theme (Willmott and Wellens, 2004). Alongside a number of generic skills, such as teamwork, researching of material and the use of web-authoring software, the stated requirement in the exercise that all student sites should reflect the 'diversity of informed opinion' reinforces awareness of the importance of worldview in decision-making, and an appreciation for those who hold a different viewpoint.

CONCLUDING REMARKS

It is clear that teaching ethics lends itself to non-lecture forms of teaching, with emphasis on group work, interactive learning and student-centred learning. However, that is not to say that we have abandoned totally the **lecture** format, either delivered by university staff or invited speakers (see Willmott *et al*, 2004). For example, imparting the basics of ethical theory is probably best done in a lecture, but even then the lecture(s) may be punctuated by brief thought experiments and well-structured illustrations. It is also important, for any particular issue, to ensure that the students are aware of the current situation, particularly for topics that have not been covered in their more 'conventional' science courses.

Finally, it is our experience that bioethics lends itself well to development of skills in science communication. The ethical angle provides a ready-made 'hook' for engaging with the public who may well have strong views on these issues, even if not knowing much about the science. We are thus developing science communication exercises based on bioethical issues and hope that these will equip our graduates to **communicate clearly** with wider audiences.

REFERENCES

Ashcroft, R. E. (2005) Born with two mothers. *British Medical Journal* 330:969

BBC (2004) The Dark Secret of Hendrik Schön, see http://www.bbc.co.uk/science/horizon/2004/hendrikschon.shtml (last accessed 27th April 2005)

BBC (2005) Who's Afraid of Designer Babies?, see http://www.bbc.co.uk/sn/tvradio/programmes/horizon/babies_prog_summary.shtml (last accessed 27th April 2005)

Bryant, J. and Baggott la Velle, L. (2003) A bioethics course for biology and science education students. *Journal of Biological Education* 37, 91-95

Bryant, J., Baggott la Velle, L. and Searle, J. eds (2002) *Bioethics for Scientists*. John Wiley and Sons, Chichester

Bryant, J., Baggott la Velle, L. and Searle, J. (2005) *Introduction to Bioethics*. John Wiley and Sons, Chichester

Channel 4 (2005) Testing times: IVF and the quest to conceive, available at http://www.channel4.com/health/microsites/F/family/baby/ivf.html (last accessed 27th April 2005)

Coppola, B. P. (2000) Targeting Entry Points for Ethics in Chemistry Teaching and Learning. *Journal of Chemical Education* 77, 1506-1511

EPSRC (2003) Joint statement on skills training, available online at http://www.epsrc.ac.uk/PostgraduateTraining/JointStatementOnSkillsTraining.htm (last accessed 28th April 2005)

Fink, R. D. (2002) Cloning, stem cells and the current national debate: incorporating ethics into a large introductory biology course. *Cell Biology Education* 1, 132-144.

Goldfarb, T. D. and Pritchard M. S. (2000) Ethics in the science classroom. Available online at http://www.wmich.edu/ethics/ESC/index.html (last accessed 28th April 2005)

QAA (2002) Benchmarking statements for Bioscience, available at http://www.qaa.ac.uk/academicinfrastructure/benchmark/honours/biosciences.pdf (last accessed 27th April 2005)

Rubin, L. M. (2004) Case Teaching Notes for 'Saving Superman: a Look into Stem Cell Research.' Available online at http://www.sciencecases.org/superman/superman_notes.asp (last accessed on April 28 2005).

Shamoo A. E. and Resnik D. B. (2003) Responsible conduct in research. Oxford University Press, New York.

Thomsen M. (1999) Learning lessons about ethics Physics World 12:15-16 currently available at http://physicsweb.org/articles/world/12/3/2/1 (last accessed April 28th 2005)

Willmott, C. (2004) Ethics and *Bioethics Bioethics Briefing No. 1* (LTSN/Higher Education Academy Centre for Bioscience), available online at http://www.bioscience.heacademy.ac.uk/resources/ethicsbrief.htm (last accessed 27th April 2005)

Willmott, C. J. R., Bond, A. N., Bryant, J. B., Maw, S. J., Sears, H. J. and Wilson, J. M. (2004) Teaching ethics to bioscience students – a survey of undergraduate provision *Bioscience Education E-journal* 3-9, available online at http://www.bioscience.heacademy.ac.uk/journal/vol3/Beej-3-9.htm (last accessed 27th April 2005)

Willmott, C. J. R. and Wellens, J. (2004) Teaching about bioethics through authoring of websites *Journal of Biological Education* 39, 27-31

[W3] The Midwich Cuckoos revisited: promoting learning through peer group work

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Keywords: peer group work, active learning, assessment, motivation, communication, autonomy

ABSTRACT

Despite increased commitment to teaching and learning throughout Higher Education in recent years there does not appear to be any clear evidence that this has resulted in improved learning by our students. We believe that a more interactive approach to learning may be needed. We argue that the introduction of peer group work into appropriate teaching activities represents one approach to promoting more effective learning. Both advantages and problems associated with group work are discussed. We argue that the beneficial effects outweigh the difficulties, besides improved learning students tend to enjoy the social interaction of group work, display increased motivation and have decreased feelings of isolation.

INTRODUCTION

Higher Education has experienced educational development and commitment to teaching on an unprecedented scale over the past twenty years. Unfortunately there does not appear to be any clear evidence for improved learning by our students during this period. This should not surprise us as George Bodner told us nearly 20 years ago that '*Teaching and learning are not synonymous: we can teach – and teach well – without having the students learn*' (Bodner 1986). It should however concern us; learning and teaching may not be synonymous but they are of course related, though the relationship is not simple. We tend to judge teaching in terms of the effort put in by the teacher whereas learning is likely to reflect the effort being put in by the learner. Alas, doing the wrong thing better is unlikely to lead to success. All too often, where a teacher increases input to try to address the learning difficulties of students, the learners are merely encouraged to reduce their own effort. Student effort is clearly a necessary condition for learning but it isn't of course sufficient; the effort also needs to be well directed. If we wish to support our students' learning, we as teachers must try to ensure that our students are making well focussed efforts to achieve the desired learning outcomes. Our current efforts would appear to be either misguided or ill focussed. We hope and believe that it is the latter and would suggest that what is needed is a more active or better still a more interactive approach to learning by our students. It is argued that such an approach can be facilitated when students are encouraged to work in groups. Such group work can easily be introduced into all conventional teaching activities including lectures, laboratories, tutorials, case studies, projects, role-play and even coursework.

Although small group work has been widely used in higher education for many years, it traditionally took the form of a teacher led tutorial. While there is little doubt that this, when done well, can offer a rich learning opportunity it undoubtedly places a high demand on staff time (Ogborn 1977). Unfortunately the recent expansion in Higher Education as we move from an elitist approach to the mass education system needed to support a knowledge-based economy has been accompanied by a decrease in both unit funding and staff to student ratios, making this former approach hard to facilitate. This has led to claims that students must start to take more responsibility for their own learning and has encouraged the search for innovative approaches to teaching which place a reduced burden on the teacher. Widespread use of computers and information technology represents one such approach, cooperative learning and peer group work another. Despite the enormous investment of resources and time in applying computers to education, to date evidence of improved subject specific learning has remained elusive (Bodner 1997). In general, evidence of the benefits of peer group work appears more easily found (Dougherty *et al*, 1995; Kogut 1997). The possibility of duplicating the situation described in John Wyndham's classic book, where once anything is learned by an individual in the group, all the rest of the group simultaneously acquire the knowledge, remains an impossible dream (Wyndham 1960). However, there is little doubt that students can learn much from each other and learning in peer groups offers an attractive option in the present climate. An excellent introduction to the area has recently been updated (Jaques 2000).

ADVANTAGES OF PEER GROUP WORK

It is important not to confuse the product with the medium. Learning is the desired end product and peer groups are only significant in so far as they serve to promote this. Fortunately there are sound pedagogical reasons to believe that working in peer groups can potentially promote efficient learning (Dougherty *et al*, 1995; Spencer 1999). Significantly, working in such groups requires the learner to assume a more active /interactive role than normal by formulating ideas and exchanging opinions with peers. Ideally this can promote a meaningful dialogue. While most students are unwilling to question their teachers, believing that differences in opinion reflect their own lack of understanding, they are in general much more likely to disagree and debate with classmates. Such interactions not only encourage meaningful learning but are also likely to enhance time on task, a frequently neglected aspect of learning (Byers 2001). Studies have shown that group work can lead both to improved learning in terms of reproduction, understanding and application (Sisovic and Bojovic 2000) and to improved attitude towards science (Shibley and Zimmaro 2002). Students are likely to benefit from having a topic sympathetically explained by peers who only recently understood it themselves and can still remember the difficulties encountered. The benefit to the peer tutor is probably even greater as the effort required to express a concept in your own words, so it can be explained to others is, as all teachers surely know, a very rich learning experience (Coe *et al*, 1999)

A large majority of students like group work and find it motivating. It tends to decrease the feeling of isolation and promotes friendship and pro-social behaviour. Group work employed early in a course may well therefore assist retention. (Towns *et al*, 2000). It can also help to develop a wide range of generic attributes including communication and interpersonal skills as a by-product of subject specific learning (Duprey *et al*, 2003). Group work frequently enables the learners to be given part ownership of the process, enhancing motivation and perseverance (Sharan and Sharan 1990). We therefore believe that peer groups should be encouraged to be as autonomous as possible with the teacher only intervening when it is clear that the group are in danger of making serious mistakes. Group work can permit tasks too large for an individual to be successfully completed and individual learners within a group are likely to approach even difficult tasks with greater confidence.

PROBLEMS WITH PEER GROUP WORK

Although peer group work offers significant advantages to learners there are also a number of potentially serious disadvantages. Most noticeably, although most students appear to enjoy the social interaction of group work, it is only with experience that they begin to function efficiently as team members (Byers 2002). This is consistent with suggestions by Garratt that students need to become familiar with any new learning approach before they can be expected to engage fully with it (Garratt 2001). The importance of preparing students to undertake group work has been stressed by Towns (Towns 1998). Friction or a lack of cohesion within a group can quickly inhibit expected learning benefits. Our own work has shown that while the vast majority of students in a class were in favour of working in groups, virtually all suggestions for improving the experience reflected problems within groups and voiced the recurring complaint that some students were not pulling their weight (Byers 2002). This is an oversimplification as clearly there are many reasons why interpersonal tensions may build up in groups. Common problems occur with 'know it all experts' who are not prepared to consider ideas from other people, 'hitchhikers' who are happy to express opinions but do no productive work, 'lurkers' who are happy to carry out tasks, often the more mundane ones, but never express opinions and probably worst of all aggressive individuals. With experience, group cohesion usually improves and it is interesting and encouraging that after taking a cooperative learning course several students going on to a conventional course independently formed their own learning groups (Kogut 1997). Poor communication seems to be a major problem affecting much group work; in particular the oral communication skills exhibited by many students are poorly developed. While group work will help to develop these skills the lack of them is likely to inhibit progress in the short term.

A difficult problem that we have encountered is the conflict between Learning and Team Work. Unfortunately if a group is given a task, there is a tendency to try and have each part of the task carried out by the individual who is already best at this task: titrations by the most competent practical worker, calculations by the most numerate and oral presentations by the most confident. While this may well yield the best result it certainly isn't likely to promote the most effective learning, which is surely our aim. It is therefore important that students be encouraged to work on aspects where they may be lacking confidence. We call this approach 'let's play George (or should it be Wayne?) in goal.' Obviously if you had a football match to win you would have played George Best in attack but he may well have learned more if he'd been played in goal. Students can be encouraged to think about their learning priorities by asking them to fill out pre-activity questionnaires in which they indicate what they consider to be their strengths and weaknesses with respect to the tasks that will be required. Students can then be encouraged to take on tasks for which they have identified a particular weakness while group members identifying this as an area of strength can be encouraged to support and help if needed. Such an approach while pedagogically sound may well be undermined by a conventional approach to assessment.

Assessment can lead to difficulties in any teaching scheme but it is a particular problem for group work where the value of individual contributions to the group effort is invariably difficult to quantify. Some would suggest that assessment and rewards of any kind tend to inhibit rather than enhance group learning by encouraging competition rather than cooperation (Kohn 1991); this has however been strongly challenged by Slavin who argues that the use of rewards and grades in group learning is likely to be beneficial (Slavin 1991).

Our own approach is to encourage and reward effort to learn and inclusiveness rather than just the final product. Wherever possible for summative assessments we try to include both a group and an individual component to the assessments. For formative work it seems particularly important to try and encourage effort from all students. Here we have had considerable success with our own version of Russian roulette: several groups of students are given the same assignment to tackle and after a suitable interval a dice is rolled or lots drawn to decide which group will make a presentation to the class. Five minutes are allowed for the 'lucky' group to prepare a single overhead to help present their findings and the dice is rolled again to select the individual who will make the presentation on behalf of the group. Individual presentations are followed by a general class discussion. While a few students express initial concern about this approach they quickly come to appreciate the supportive atmosphere that characterises the presentations and begin to enjoy the experience.

Students working in groups to solve problems frequently show a lack of ambition, the lullaby effect (Bigge *et al.*, 1999). Once an answer is obtained there is often little attempt to look for any better alternatives. However, when faced with the prospect of having to present ideas to 'rival groups' there is evidence of deeper thinking.

FACTORS TO BE CONSIDERED WHEN EMPLOYING GROUP WORK

Probably the first thing to be considered is why peer group work is appropriate for the task to be tackled and how learning outcomes can be facilitated through group work. In general it appears that open-ended problems that require high levels of interaction offer richer learning experiences than routine tasks (Cohen 1994). The next consideration should be the size of the groups to be used. Ideally, if everyone is to be kept occupied, group size will be determined by the demands of the task. There is little point in asking a group of six to attempt a task that could readily be completed by any two of them. Of course practicalities like a lack of time or resources may on occasion mean that the ideal can't be met. In general as group size increases the more complex and more interesting the problem to be tackled can be. However the chances of an individual becoming completely inactive rises with increasing group size as does the number of interpersonal interfaces and the differences in contribution made by individual group members. As group size increases the likelihood of a group splitting into two, like a liquid drop, increases.

A further consideration is how groups should be selected. Most students prefer to select their own groups. However such an approach is likely to result in groups of widely varying ability and will frequently leave a disenchanted few to form a remnants' group at the end. It can also be argued that as students will be unlikely to be able to choose the people they will work with in future employment, a better if not more enjoyable experience is provided by not allowing them to choose their own groups. An alternative approach is for the tutor to choose the groups in an effort to make them as balanced, inhomogeneous and equal as possible. There is much to recommend such an approach but if done conscientiously it is likely to be time demanding and will invariably result in some individuals complaining about the way the groups were assigned. Probably the best approach in general is merely to assign students into groups on some random basis. We would include alphabetical order as a random assignment in this case. Ultimately the choice should be made with the desired learning outcomes for the exercise clearly in mind.

However we select our groups, or whatever size they are, it is vital that we provide unambiguous group goals and a clear picture of how individual accountability will be measured.

SOME EXAMPLES OF PEER GROUP WORK

Group work can be introduced into any conventional teaching activity as exemplified below. It is important however to be clear about the learning benefits we expect when employing group work in any activity.

Lectures: Although lectures are not the ideal medium to support group work, buzz groups can be used to promote learner activity, to encourage students to think about key issues before proceeding (Byers 1997) or just to introduce a break (Wenzel 1999). Group work has also been suggested as a partial alternative to a traditional lecture programme (Allison 2001)

Laboratories: Practical work is often well suited to small group activities. Routine expository and verification experiments can be made more stimulating by introducing an open-ended inquiry or project dimension (Hunter et al, 2000; Byers 2002).

Tutorials: Tutorial problems can usually be tackled by an individual, but group work encourages brainstorming and the need to formulate, communicate and possibly defend one's own ideas. Controversy leading to consensus has been shown to be particularly effective in promoting meaningful learning (Smith *et al*, 1981).

Case Studies: Case studies are usually multidimensional, making them particularly suited to group work.

Role-Play: Role-play really requires a group setting. It can be used to create competition or antagonism between groups. This in turn promotes good cohesion within the groups (Byers 2002).

Specific examples of group activities in a range of activities will be discussed in the workshop and participants will be encouraged to identify aspects of their own teaching where the introduction of peer group work is likely to be beneficial.

CONCLUSIONS

Working in peer groups provides a potentially rich learning environment that can be used with a wide variety of teaching activities. We would not claim that it provides a solution to all learning difficulties and would urge that clear pedagogical reasons are identified before any group work is introduced. However where conventional teaching is not producing the desired learning outcomes we recommend that consideration be given to whether the situation is likely to be improved by the introduction of peer group activities.

REFERENCES

Allison, J. (2001) A model for Substantial Deviations from the Traditional Lecture Format for Graduate and Upper-Level Undergraduate Courses in Science-Lecture and Learning Classes. *Journal of Chemical Education*, 78, 965-969.

Bigge, M. S. and Shermis, S. (1999) *Learning Theories for Teachers, 6th Ed*., Longman, New York, London, p285.

Bodner, G. M. (1997) Confessions Of A Modern Luddite: A Critique Of Computer-Based Instruction. *CAL-laborate*, October, 2-4.

Bodner, G. M. (1986) Constructivism: A Theory of Knowledge. *Journal of Chemical Education*, 63, 873-878.

Byers, W. (2002) Using Student-led Pre- and Post-lab Sessions to Promote Active Learning in Small Group Practical Classes. *University Chemistry Education*, 6, 28-34.

Byers, W. (2001) Using questions to promote active learning in lectures. *University Chemistry Education*, 5, 24-30.

Byers, W. (1997) Don't Throw the Baby out with the Bathwater. *Proceedings of the 4th European Conference on Research in Chemical Education* (University of York) p52.

Coe, E. M. McDougall, A. O. and McKeown, N. B. (1999) Is Peer Assisted Learning of benefit to undergraduate chemists? *University Chemistry Education*, 3, 72-75.

Cohen, E. G. (1994) Restructuring the Classroom: Conditions for Productive Small Groups. *Review of Educational Research*, 64, 1-35.

Dougherty, R. C. Bowen, C. W. Berger, T. Rees, W. Mellon, E. K. and Pulliam, E. (1995) Cooperative Learning and Enhanced Communication: Effects on Student performance, Retention and Attitudes in General Chemistry. *Journal of Chemical Education*, 72, 793-797.

Duprey, R. Sell, C. S. and Lowe, N. D. (2003) The Chemistry of Fragrances: A Group Exercise for Chemistry Students. *Journal of Chemical Education*, 80, 513-515.

Garratt, J. (2001) Questionable questions. *University Chemistry Education*, 5, 40-41.

Hunter C. Wardell S. and Wilkins H. (2000) Introducing first-year students to some skills of investigatory laboratory work. *University Chemistry Education*, 4, 12-15.

Jaques, D. (2000) *Learning in Groups 3rd, Ed*., Kogan Page, London.

Kogut, L. S. (1997) Using Cooperative Learning To Enhance Performance in General Chemistry. *Journal of Chemical Education*, 74, 720-722.

Kohn, A. (1991) Group Grade Grubbing versus Cooperative Learning. *Education Leadership*, 49, 83-87.

Ogborn, J. Ed. (1977) Small Group Teaching in Undergraduate Science. Heineman Educational Books, London.

Sharan, Y. and Sharan, S. (1990) Group Investigation Expands Cooperative Learning. *Education Leadership*, 47, 4: 17-21

Shibley, I. A. and Zimmaro, D. M. (2002) The Influence of Collaborative Learning on Student Attitudes and Performances in an Introductory Chemistry Laboratory. *Journal of Chemical Education*, 79, 745-748.

Sisovic, D. and Bojovic, S. (2000) Approaching The Concepts Of Acids And Bases By Cooperative Learning. *Chemical Education: Research and Practice In Europe*, 1, 263-275.

Slavin, R. E. (1991) Group Rewards Make Groupwork Work. *Educational Leadership*, 49, 89-91.

Smith, K. Johnson, D. W. and Johnson, R.T. (1981) Can Conflict Be Constructive? Controversy Versus Concurrence Seeking in Learning Groups. *Journal of Educational Psychology*, 73, 651-663.

Spencer, J. N. (1999) New Directions in Teaching Chemistry: A Philosophical and Pedagogical Basis. *Journal of Chemical Education*, 76, 566-569.

Towns, M. H. Kreke, K. and Fields, A. (2000) An Action Research Project: Student Perspectives on Small-Group Learning in Chemistry. *Journal of Chemical Education*, 77, 111-115.

Towns, M. H. (1998) How Do I Get My Students To Work Together? Getting Cooperative Learning Started. *Journal of Chemical Education*, 75, 67-69.

Wenzel, T. J. (1999) The Lecture as a Learning Device. *Analytical Chemistry*, 71, 817A-819A.

Wyndham, J. (1960) *The Midwich Cuckoos*. Penguin, Harmondsworth.

[W4] The best of both worlds? Experiencing research through teaching

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Keywords: science teaching, linking teaching with research, case studies

For many academics the link between student learning and staff research within their own discipline lies at the centre of what is distinctive about higher education. There is a strong tradition across the sciences of linking research with teaching and evidence that students value and are motivated by the experience of studying in a research-rich environment.

However, do you explicitly articulate for your students, colleagues and yourself that activities used in your teaching are based on the research process? Do students understand the research environment within their department? Could the link between teaching and research be made more explicit and exploited more effectively for the benefit of staff and students?

The main aim of the workshop is to challenge you to review and evaluate existing practice within your department and to think about ways of developing and integrating research practice into your teaching.

You will have the opportunity to:

(1) discuss the teaching-research 'nexus' in the context of your discipline;

(2) reflect how students experience the research context in your department;

(3) review a wide range of ideas (presented through short case studies) of how to integrate research into teaching;

(4) consider how the above ideas could be applied to your teaching practice.

A report of the workshop outcomes will be made available on the conference website.

REFERENCES

Jenkins, A. and Zetter, R. (2003) Linking Research and Teaching in Departments. York: LTSN Generic Centre. Available at: http://www.heacademy.ac.uk/resources.asp?process=full_record&section=generic&id=257 (accessed 19 May 2005)

Sears, H.J. and Wood, E.J. (2005) Linking teaching and research in the biosciences. Bioscience Education E-Journal volume 5 available at http://www.bioscience.heacademy.ac.uk/journal/vol5/beej-5-4.htm (accessed 19 May 2005)

LINKS

Higher Education Academy Subject Centre for Bioscience: Linking Teaching and Research in the Biosciences: http://www.bioscience.heacademy.ac.uk/projects/ltr/

Higher Education Academy: Linking Teaching and Research: http://www.heacademy.ac.uk/850.htm

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Professor Alan Jenkins for advice, encouragement and unstinting enthusiasm throughout (and beyond) the 'Linking Teaching and Research in the Disciplines' project. The LTSN Generic Centre for funding.

[W5] e-learning and disability: tales from the riverbank (and other non-classroom based learning environments)

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There are many reasons for using technology to support learning and teaching, in the sciences there is often excellent opportunities to further extend the technology into the non traditional learning environments that, whilst not unique, are more prevalent in the sciences, such as fieldwork and laboratory work. The diversity of these resources can range from a simulation demonstrating the working of a mass spectrometer to immersive ecological sampling in multiple dimensions. The range of technology involved is also staggering, some may be simple webpages, designed as an introduction to a 'real' field or lab exercise – whilst some may be highly interactive software programs written specifically or even technology designed to be worn and collect data.

Whilst the provision of these resources may well bring benefits there can be no doubt that in the initial stages of either development of a new resource or the implementation of an existing resource a cost will be incurred in both labour and finance. However, the technology, as well as benefiting learning and teaching, can have other roles such as improving the management of learning. It could be argued that the provision of technology in this way is a natural progression in the increase in interactivity previously identified by Kent *et al* (1997), trying to engage students in another form of communication in what is to all intents and purposes another environment. It may be, in the future, that as the Internet becomes more interactive, using Lonergan and Andresen's (1988) fieldwork definition, students spend time interacting and studying 'cyberspace' as a field course in its own right.

Disabled students in sciences often face specific problems of access to some of the non-classroom based activities that studying science entails. This area has already being touched upon in the GDN guide 'Issues in Providing Learning Support for Disabled Students Undertaking Fieldwork and Related Activities' (Healey *et al* 2001). Previously it has been suggested that the development of technology to replace this kind of activity can be detrimental to the sector. The development of technology-based replacements for use by disabled students not participating in lab or fieldwork, and with the same learning outcomes being met, may negate the need for 'real' activities (Phipps 2001).

In this workshop the aim is to discuss some of the key issues surrounding the approach of providing 'digital alternative representations of reality' (Stainfield *et al*, 2000) to support disabled students, widening the focus and bringing together the experience of other subjects using e-learning and identify what issues are most important both for students and the whole course. However, this is set against a background of standards and guidelines designed to support access to electronic or technology based material for disabled people. In addition standards are being developed and applied to e-learning. The workshop will open with perspectives on disability from practitioners in the science education community and with perspectives on e-learning from disabled students before opening up to the discussion on digital alternatives and associated issues.

In addition the workshop will look at some of the ways that technology has been used effectively to support lab and fieldwork for disabled students and will include a live demonstration of low cost technology being used in a learning situation – from a riverbank and into Warwick University.

The workshop is supported by the Poster 'Digital Alternatives and Disability in Science Education' and delegates are encouraged to annotate the poster with their own comments, thoughts and ideas.

REFERENCES

Healey M., Jenkins A., Leach J. and Roberts C (2001) Issues in Providing Learning Support for Disabled Students Undertaking Fieldwork and Related Activities. University of Gloucester and HEFCE

Kent M, Gilbertson D. D., Hunt C. O. (1997) Fieldwork in Geography Teaching: a critical review of the literature and approaches, Journal of Geography in Higher Education, 21 pp. 313-332

Lonergan N. and Andreson L. W. (1988) Field-based education: some theoretical considerations, Higher Education Research and Development, 7, pp. 63 – 77

Phipps L. (2001), Another Node on the Internet, Reflections on virtual fieldwork , Computers and Geosciences 27, Pergamon

Stainfield J., Fisher P., Ford B. and Solem M. (2000) International Perspectives on Virtual Fieldwork. Symposium on International Fieldwork, Journal of Geography in Higher Education.

[W6] Introduction to problem-based learning

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Explore the benefits and processes of problem-based learning (PBL) and discuss routes to implementation on various scales.

This workshop will contain group activities and discussion, and is aimed at teaching staff and curriculum developers with little or no experience of PBL.