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REPORT

1st Year Practicals: Their Role in Developing Future Bioscientists

A report of a workshop for invited participants organised by the Centre for Bioscience and sponsored by AstraZeneca Pharmaceuticals and the BBSRC Weetwood Hall, University of Leeds, 7-8 April 2008

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Contents

1. Recommendations and executive summary

This report contains a summary of the main points emerging from a workshop, arranged by the Centre for Bioscience, Higher Education Academy, to discuss the topic of first year undergraduate practical work in the biosciences.
The recommendations are:

A) Strategy and coordination

A1. Effective communication channels need to be established across the range of stakeholders [a] with interests in the effectiveness and appropriateness of university-level bioscience laboratory classes.
A2. Together these stakeholders should develop an overarching strategy addressing the practical abilities and motivation of bioscience graduates in the context of bioscience laboratory careers.
A3. Consideration needs to be given to the alignment of practical work across the 1st and later years of degree programmes so the student experience is a continuum from 1st to final year.

B) Awareness raising

B1. The results of the survey [1, 2] and this workshop should be widely disseminated and owned by bioscience teachers involved in practical/laboratory work.
B2. A digest should be commissioned and made readily accessible to bioscientists of the literature on the nature and effectiveness of practical/laboratory work in universities, on what makes for good practical/laboratory work and innovative approaches to improve the practical/laboratory work experience.
B3. The features of good practical/laboratory classes should be made known to students so they can evaluate what they receive and become drivers for improvement.
B4. A list of practical laboratory skills which employers would wish to see in graduates seeking laboratory-based employment should be compiled and disseminated.

C) Training and funding

C1. The Centre for Bioscience (with appropriate partners) should explore the feasibility of developing a bioscience Dynamic Lab/Field Manual [b] for use by contributing institutions.
C2. The Centre for Bioscience should work in partnership with stakeholders and the Higher Education Academy to lobby for appropriate resource to support practical work.
C3. Consideration should be given to motivating and rewarding staff who develop practicals.
C4. Good practice guidelines for the training of demonstrators and laboratory staff in practical work itself and its assessment and in appropriate attitudes to students and teaching should be produced.
C5. Consideration should be given to facilitation of one day workshops to reduce the isolation and individual activity, and for interested parties to get together locally for specific tasks such as the development of new practicals, which could then be shared.
C6. Consideration should be given to greater communication between school teachers and staff involved in 1st year practicals and the level at which this is arranged (departmental, institutional or national).

D) Developing and sharing good practice

D1. Further examples of good practice and/or change should be identified and individuals funded to write case studies to be published in 2009 as an addendum to this report.
D2. Consideration should be given to consolidating and developing the Centre for Bioscience's Practical Compendium [c].
D3. The desirability and feasibility of piloting a discipline-based 'consultative forum' should be explored, to which academic staff could voluntarily submit practicals for review and comment. Formats including a 'staff summer school' approach should be considered.

cont.

[a] [*e.g.* bioscience undergraduates, university teachers, HUBS (Heads of University Biological Sciences), Sector Skills Councils, employers, bioscience associations including the Biosciences Federation and the Institute of Biology, the UK higher education funding councils, the Centre for Bioscience, the BBSRC, and school teachers]
[b] http://newmole.chm.bris.ac.uk/dlm-demo17a/
[c] www.bioscience.heacademy.ac.uk/compendium/default.aspx

D4. The Centre for Bioscience should consider engaging with school biology teachers to explore the transition issues between school and university (see also C6).
D5. A survey should be conducted of current practice across all bioscience departments to identify and then exploit/adapt effective practice which addresses the issues discussed in the workshop.

The workshop was held at Weetwood Hall, Leeds, 7-8 April, 2008 and focussed on the disciplines of biochemistry, physiology/biomedical sciences, microbiology, pharmacology and field biology. The first four discipline areas involve predominantly laboratory-based practical work and were chosen since they constitute a core element of the first year of the majority of BSc bioscience programmes; field biology was included to explore potential contrasts. Thirty-two invited participants contributed.

Workshop participants discussed a number of issues including:

- the purposes and hence the desirable learning outcomes for 1st year practicals in the biosciences
- the constraints and limitations on laboratory and practical work, including those posed by large student cohorts, and availability of funding, support staff and other resources
- the need for and better ways of managing the transition from school to university practicals
- the importance of engendering 1st year students with enthusiasm for laboratory work (and bioscience) and laboratory-based careers, the case for stipulating this as an explicit outcome of first year practicals, and the importance of teaching staff, postgraduate demonstrators and technicians conveying enthusiasm to students
- the importance first year students place on social interaction [3] as part of their learning experience and the importance of this element to good practicals
- the need for the development of more good practicals and guidelines for good practical design, including the importance of presenting practical content in appropriate context(s); incorporating an inquiry mode or defining problem(s) for students to tackle; including an open-ended element or creating room for experimental design by students, as being the key to engagement and active learning
- when designing or redesigning practicals, the importance of planning learning outcomes across modules and all years of degree programmes
- teaching staff needing to reclaim a teaching role within practicals and not simply an organising role
- whether there is a need for the collaborative development and/or sharing of practical designs and details of literature pertaining to practical design
- whether there is further need for research into student perceptions of practicals and associated learning needs
- the stakeholders in university level bioscience practicals and the need for improved communication and a partnership approach to future work in this area.

Participants shared their experiences of designing and delivering 1st year practicals and redesigned a number of practicals addressing the issues identified as important to students.

In the course of the workshop and subsequently, a number of recommendations were identified and are detailed above. As far as possible the Centre for Bioscience will work collaboratively with appropriate partners to take forward these recommendations to assist university-level bioscience units in providing the best practical experience for their students.

2. Background

It has been reported by some employers (ABPI survey [4]; Biosciences Federation [5, 6]; SEMTA [7, 8]) that there is a shortage of appropriately skilled graduates in some bioscience areas, particularly with regard to graduates with laboratory skills and aptitudes. Within these reports two separate but related issues can be identified:

a) the number of available practically skilled and motivated graduates
b) the extent to which available graduates are appropriately skilled.

This shortage of graduates may seem unexpected at a time when the total number of students attending university courses has expanded greatly (a 29.5% increase over 10 years: Table 1).

Table 1. Student numbers 1996/97 to 2006/07

Year	Total student entry to higher education	JACS Code C student numbers	JACS Code C minus Psychology & Sports Science students
1996/97	1,392,607	64,330	44,125
2002/03	1,677,615	100,585	44,675
2006/07	1,803,475	133,225	46,445
Increase over period	**+ 29.5%**	**+ 107.0%**	**+ 5.2%**

However, although biological science student numbers (JACS Code C [9]) have expanded even more markedly (a 107% increase over the same period), when Sports Science students and Psychology students (also classified under JACS Code C) are removed from the calculation, it is clear that the number of students studying traditional biological science programmes has increased less than proportionately to overall student numbers (only a 5.2% increase) [10]. It should be noted however that some additional students studying biosciences will be included under other JACS codes, for example Industrial Biotechnology (J700) or Anatomy (B100); the latter discipline increasing student numbers from 5,095 to 16,930 (+300%) over the same period.

Whatever the actual increase in students studying biosciences, several factors will impinge on the number of bioscience graduates available to take employment in a laboratory context and on their suitability to do so:

- bioscience graduates enter an increased range of employment – indeed some 50% of bioscience graduates now take employment outside the biosciences [11]
- university entrants have a much wider range of knowledge, skills, motivations and aspirations than was previously the case in many universities
- degree programme entry numbers have increased dramatically, for example in one institution from 18 to over 100 over 20 years. Not only have entry numbers increased but modularisation means a given module may be taken by students from several degree programmes leading to large class sizes and reduced options for practical work
- practical work is expensive in terms of consumables, staff time and building costs and there is now a much sharper focus on the cost/income balance of individual modules. In addition, the funding of bioscience students as band B at 1.7FTE means the unit of resource has fallen and it is difficult to fund the levels of practical work previously common
- what can be done with available resources for 10 students simply cannot be done with over 100 and therefore the nature of laboratory/practical work has changed. In addition the resource implications of having to staff repeat laboratory classes to accommodate all students can be considerable, providing further pressure to reduce practical work
- the increasing inclusion of the explicit teaching of generic skills in programmes has led to pressures on time in the curriculum. Time has been released in many cases by a reduction in laboratory experiences available to students
- where options of practical light or practical heavy modules are offered students may increasingly opt, in first year at least, to take practical light modules as they are perceived to be the easier option, are less demanding in student time, or because of the often extensive assessment associated with the laboratory class
- the reduced experience of practical work in school [12] may also contribute to students being ill-prepared [13] for what they experience in first year practicals at university

- the laboratory classes experienced by 1st year students often do not represent an exciting and motivating experience and may deter some students from pursuing practically-orientated programmes that may lead to laboratory-based careers in bioscience.

To investigate this latter point the Centre for Bioscience, in conjunction with AstraZeneca, surveyed first year students taking bioscience courses as to their views on the laboratory courses they had experienced [1, 2]. A summary of the findings of the survey is given below.

i. Most students preferred the laboratory classes they had experienced at school to those they were experiencing at university.

ii. Students identified the following as the **best** features of their university laboratory classes:
   - learning new skills and using new equipment
   - the opportunity for social interaction with students and teachers
   - the function of practicals to illustrate material given in lectures
   - the acquisition of new knowledge through practical classes
   - the high interest value of practicals.

iii. Students identified the following as the **worst** features of laboratory classes:
   - the excessive length of practicals
   - the poor organisation
   - the associated write-up
   - the tedious/boring/repetitive nature of practicals
   - the variable contribution of staff.

To take forward the findings of this survey the Centre for Bioscience and AstraZeneca Pharmaceuticals invited 32 individuals to meet for a workshop at Weetwood Hall, University of Leeds, from April 7th to 8th 2008. The overall aims of the workshop were:

a) to discuss and define the issues uncovered by the survey
b) to start to address some of the specific issues raised
c) to instigate development of a strategy, involving all stakeholders, to address the problem of practical/laboratory work in bioscience degree programmes at all levels.

An account of the proceedings, findings and recommendations of this workshop is the substance of this report.

3. Intended outcomes

Invited participants to the workshop were chosen to represent the range of bioscience disciplines including Biochemistry, Physiology and Biomedical Sciences, Pharmacology, Microbiology and Field Biology. In this way, it was hoped that the findings would have a broad applicability across the Biosciences. Attention was focussed almost exclusively on 1st year practicals and laboratory classes though the intention is, in other events, to address similar issues in later years of bioscience programmes.

The intended **outcomes** from the workshop were:

a) a better understanding by participants of reasons why students do not view 1st year practicals as a wholly satisfactory experience
b) a report of the findings, discussion and conclusions of the workshop including examples of how the student experience of laboratory work in 1st year could be improved and the identification of any constraints on such improvements
c) to publicise a range of examples of good practice in arranging practical work for 1st year students
d) to encourage a number of participants to make changes in their 1st year laboratory courses and to evaluate and report on the outcomes

e) to agree a process to develop a strategy for increasing the competence of bioscience students with regard to practical work and their enthusiasm for laboratory-based careers.

The content in subsequent sections of this report is organised according to the programme for the workshop, which was as follows:

Day 1 – 7 April	
4.45 pm – 6 pm	**Report on the Student View of 1st year Laboratory Work in Biosciences** Ian Hughes
Day 2 – 8 April	
8.45am	Practitioner presentations: **Engaging and enthusing students in practical science** Dr David Smith and Dr Tom Podesta, Bristol ChemLabS **The Dynamic Laboratory Manual – an on-line interactive resource for promoting practical teaching** Dr David Smith and Dr Tom Podesta, Bristol ChemLabS **Inquiry-based learning in a first year biology laboratory class** Dr V Anne Smith and Dr Morven Shearer, University of St Andrews
10.30 am	**Group Activity – Redesigning practicals** (in discipline groups), led by Ian Hughes
11.45 am	**Feedback from Group Activity followed by facilitated discussion –** How might the bioscience community support development of "better" practicals? led by Ian Hughes and Martin Todd

4. 1st year practical work in the biosciences

4.1. Report on the student view of 1st year laboratory work in biosciences

Ian Hughes, Centre for Bioscience; i.e.hughes@leeds.ac.uk
Presentation summary; slides at www.bioscience.heacademy.ac.uk/events/themes/practicals.aspx

In March-April 2007 students registered on 1st year bioscience courses in nine universities were surveyed, using a written questionnaire distributed by course tutors, as to their views on the laboratory classes they were taking. Returns were obtained from 695 (70%) of students surveyed.

Students rated their laboratory classes as only moderately stimulating, fascinating or enjoyable and were disappointingly neutral about wanting more practicals in 1st year and about choosing practically heavy modules in 2nd year. Disturbingly most students preferred the laboratory classes they had experienced at school to those they were experiencing at university.

Student views were varied. A number viewed some features of laboratory classes as 'good' while others viewed the same features as 'bad'. However, students identified as the **best features** of laboratory classes:

- learning new skills and using new equipment
- the opportunity for social interaction with students and teachers
- the function of practicals to illustrate material given in lectures

- the acquisition of new knowledge through practical classes
- high interest value of practicals.

Students identified as the **worst features** of laboratory classes:

- the length of practicals
- the poor organisation
- the associated write-up
- the tedious/boring/repetitive nature of practicals
- the variable contribution of staff to both the efficient organisation of classes and the effective teaching of them.

Based on student responses a range of improvements could be made to 1st year laboratory classes; in outline these are:

a) increase the effectiveness and consistency of staff in TEACHING (as opposed to only running) laboratory classes
b) recognise the importance to students of knowing peers in their class and their teachers, and engender the formation of friendship networks
c) incorporate an explicit objective of enthusing and interesting students in practical work to address perceptions that 1st year practicals are long, boring and tedious
d) restructure practicals which involve too much *'waiting around'*
e) support students to shift from a heavy emphasis on using equipment to what it enables them to do
f) create a more informal environment (more akin to that in schools) to allow students to enjoy practicals and address the difficulty that in the first few university practicals, everything and everybody is new to students
g) recognise and take steps to ameliorate the magnitude of the transition students undergo from school to university type work and environment
h) accommodate diversity in student cohorts by avoiding a one-size-fits-all approach.

4.1.1 Specific comments and discussion on the survey results

- Many of the issues highlighted suggest the Learning Outcomes (LO) of practicals should be better thought through. Consideration should be given to the LO of the entire practical programme not individual practicals in isolation. This integration might beneficially extend to all years of a programme so the practical/laboratory experience is arranged as a continuum throughout the degree programme.
- The survey highlighted the importance of the social aspect of practicals for many students. This may be particularly important for those students who are part of large first year cohorts and/or spend much of their time outside formal classes in employment. Both of these militate against students developing good social inclusion networks. Consideration should be given to the duration/nature of practical classes so they permit social interaction and assist students to 'feel at home' and part of a student group. Lecture groups are often even larger and individual students may feel isolated and have no sense of belonging.
- Working in practical groups often involves 'exposure' to the possibility of making a mistake, of misinterpreting an instruction or revealing a misunderstanding or lack of knowledge, or being ridiculed (several student comments in the survey were critical of staff who were sarcastic about students' abilities). Students may be happier to risk 'exposure' in an environment were they have established social links with other students and with staff.
- One attendee expressed surprise that students (responding to the survey) had not highlighted numeracy as being an issue. [Note adverse comments about 'calculations' were occasionally made by students.]
- Regarding the students' responses pertaining to career choice we cannot know from the survey data whether we, as university teachers, have discouraged or encouraged students to opt for bioscience-related employment. It would seem reasonable however that given the choice, students who have not enjoyed laboratory work in 1st year would be less likely to opt to take extensive laboratory work in 2nd year.
- Surveys in themselves will not lead directly to better practicals but it may be appropriate to gather and disseminate further evidence on practical work provision from students, staff or the literature. For example:
    - □ a commissioned review of the literature available on practical work in the biosciences and its influence on student career choices

- □ a compilation of the nature of the practical work undertaken by first year bioscience students at different universities
- □ a review of the effect of class size on student perceptions of first year practicals
- □ a review of the methods available to handle large practical classes successfully.

4.1.2 General discussion

- **Transition** is a key issue. There is a big change in the nature of practical work between school and university (also applies to other aspects of study [14]). The situation in bioscience resonates with Chemistry where students may 'drop out' of the subject after AS-level because of the change in level of the subject which leads to a big shock when they encounter Chemistry at university level. It may be that the jump from A-level to the first undergraduate year is similar to the acknowledged GCSE to A-level jump. In managing the transition, sometimes there is a need to make things easier for students; at other times it is appropriate to reassure them while challenging them. Recognising and managing the school/university transition needs attention.
- Different students may feel more or less **confident about entering a laboratory/practical classroom** depending on the amount of hands-on practical experience they have had previously. Without (recent) school experience of practicals, mature students may be even less sure about going into practicals. The confidence issue needs to be addressed as part of the transition to university practicals.
- **Continuity of staff** is important for students – it helps students to know their teachers. As part of their teaching developments, Bristol ChemLabS have appointed two teaching lab managers – this initiative has been successful – these staff take an overview of practical work across the degree programme and act as a single point of contact for students (other staff and demonstrator support is also available). Constantly changing staff disrupts establishment of the student/teacher relationship which students regard as important.
- Practicals should be designed as a **coordinated programme of provision** rather than piecemeal. This co-ordination should extend beyond the module to cover the entire student practical/laboratory experience, preferably across all years of the degree. The University of Manchester is one university to have successfully adopted this approach (they have in excess of 500 first year bioscience students).
- Unlike secondary teachers, university staff do not have ready access to a **bank of core practicals** – perhaps such a resource would be helpful (this would not be to specify a core curriculum though) – one recommendation might be to develop new practicals or improve sharing of existing practicals (e.g. by expanding and developing the Centre for Bioscience's Practical Compendium, although success would rely on contributions by individuals which has proved difficult in the past). The Society for General Microbiology has an excellent 'Sourcebook of Experiments for Teaching Microbiology' [15] and sets a useful precedent for other bioscience discipline areas, which might develop similar resources in conjunction with the appropriate learned society.
- It was widely thought to be important that bioscience teachers should do everything possible within first year practicals to ensure **students are enthused.** Many biomedical science students embark on their degrees uncertain of the direction they want to go in – **enthusing** them in the first year may encourage them to consider doing more practical work later in their studies and beyond. Staff attitudes are also important. A resentful demonstrator, forced to demonstrate against their will and uncertain of what the practical is about does not make a good role model. It may be better for students to meet a variety of staff and post-graduate students who are enthusiastic about and involved in laboratory work but note the second bullet point, concerning the need for students to get to know the staff.
- There may be issues with students' perceptions of the **value/relevance of practicals** in first year – for example students at some universities enter specific degree programmes but undertake generic first year modules – illustrative examples involving organisms or environments apparently out-with their programme of study may be discounted and their importance lost without very careful presentation. The context in which a laboratory exercise is set may be very important.
- **Science can be boring/tedious**. Graduates entering laboratory-based employment will need to: do sustained lab work; follow instructions/methods which are not clear; work in groups; manage their time; and work long and often unsociable hours. However, 1st year may not be the time to address these issues and in any case 1st year laboratory work can be a great distance from that experienced in laboratory employment where the worker may have all day to carry out the practical work and be able to repeat it on several days until manipulations are slick and accurate. Nevertheless there may be ways of

bringing the first year practical experience closer to that of the work environment if this is thought to be a good thing to do. Nevertheless, of students studying biosciences, 50% will take employment outside the discipline [11]. Degree programmes should provide a good and appropriate experience for all.

- **Assessment of practical work** is clearly an issue as the survey showed in that the traditional write-up takes significant amounts of student time, is often done repeatedly and does not actually assess performance in the laboratory. Conversely, one student commented in the survey with regard to practicals that 'these are pointless unless assessed'.
- An increase in student numbers and change in staff : student ratios has moved staff towards an organising role and not a teaching role in practicals *i.e.* the **teaching** has been squeezed out – we need to identify ways in which to bring it back.
- **Technical support** for practicals has greatly decreased and this poses a series of problems in certain universities. It was reported that at one university the ratio of technical staff : students was 1 : 750. This clearly limits the possibilities for practical work. **Demonstrator training** is an issue. The number of staff available for practical work can also be an issue in both fieldwork and the laboratory. Increasingly finding funding for postgraduate demonstrators is difficult and there is an increasing reluctance among principal investigators to release their laboratory staff to teach students.
- **Student time is precious** and there are plenty of other things they could be doing (academic, social or employment related) so optimal organisation of practicals is important. Teachers need to recognise that student time is valuable and students need to see that the time they spend in practical/laboratory work provides proportionate value for their learning experience in whatever currency they use.
- Enabling **social interaction** and the opportunity to build social networks is important to students but in some instances classroom management techniques may be required to avoid problems of excessive noise and students not listening.
- It was acknowledged the **classroom facilities** are very different in different institutions and people are therefore starting from different places.

4.2. Improving first year laboratory classes (presentation summary)

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Presentation summary; slides at www.bioscience.heacademy.ac.uk/events/themes/practicals.aspx

Basey, Sackett & Robinson (2008) [16], in their paper on the design of laboratory classes and student learning/attitudes identified six elements which were important to students in distinguishing between 'good' and 'bad' laboratory classes. These were:

i. the extent to which classes were exciting/boring
ii. the extent to which classes made efficient use of student time
iii. the level of difficulty of the class (easy being preferred)
iv. the extent of integration with other teaching
v. the extent to which students were 'hands on' experimenters
vi. the extent to which the design was student controlled and open ended (though this factor did not achieve statistical significance).

The above work was carried out with over 700 1st year students in the US where educational arrangements are very different from the UK. Nevertheless these elements are similar to those identified among the best and the worst features of practical classes as identified in the Centre for Bioscience survey reported previously.

4.2.1 Discussion points arising from the presentation on improving first year laboratory classes

- Results of the UK survey mesh with this study from the US. However, while it is clear that students regard 'boring' and 'exciting' as important aspect of practicals it is not clear from the data exactly what it is that makes for a 'boring' or 'exciting' practical.
- An exciting laboratory class may be an eccentric one e.g. the anecdote of a laboratory class with two snakes with students given the task of identifying which one is poisonous! Exciting practicals should involve students as more than laboratory workers – to involve them doing an investigation scientifically and critically, and requiring them to assess data and interpret it.

- The way in which practicals are presented is key – with the right context/packaging even boring or challenging activities can be stimulating, interesting, motivating and exciting.
- A further challenge is we are not just creating bioscientists but our courses must cater for the many students who will enter other careers.
- Sharing the "wow" factor with students is the reward for us as teachers.

In an attempt to improve practical classes, a variety of innovative approaches have been tried in the past and include: group practicals; problem-solving exercises; giving attention to the context in which the practical is carried out; use of learn-by-discovery methods; research-led practicals; and others. The extent to which these and other approaches can be used in the present educational environment in the UK was the topic for the remainder of the workshop and in this context participants were asked to think, over dinner, about the following:

- what are (should be?) the learning objectives of 1st year practicals?
- do we want to teach 1st year students specific laboratory skills since it will be 3 years before they reach employment?
- should we be challenging students more and letting them make mistakes? Do they see such mistakes as learning opportunities or as badly designed practicals which do not work?
- are we providing a taste for what laboratories are like and therefore informing career choices?
- are we trying to engender enthusiasm and interest in laboratory work?
- have we got the right balance between these different issues?
- not adopting a one-size-fits-all approach, can we introduce choice into practicals?
- the transition from school to university laboratory work. This is a big jump; can we help students make it in easy steps over a period of time?
- can we reduce the 'worst' things about practicals while capitalising on the 'best' things to improve the student experience of laboratory classes and so stimulate student interest and motivation for laboratory-based careers?
- is there an alternative approach (which may be very time consuming) in which staff talk to students about a negatively perceived laboratory class to show where learning can be extracted. This can be difficult if the laboratory class ends at lunch time!

5. Practitioner experiences of practical redesign and delivery

5.1. Bristol ChemLabS – approach to redesigning practical courses in chemistry

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Presentation summary; slides at www.bioscience.heacademy.ac.uk/events/themes/practicals.aspx

The Bristol ChemLabS Centre for Excellence in Teaching and Learning was established to help promote and raise standards in the teaching of practical chemistry. Refurbishment of the University of Bristol's chemistry teaching laboratories presented the opportunity to completely redevelop the existing practical courses. The new courses were developed through consultation with employers and other stakeholders and focus on the development of practical skills. The practical courses are self contained and are no longer linked directly to lecture courses, removing many of the constraints and frustrations that were, in the past, imposed by timetabling.

5.2. Bristol ChemLabS – Dynamic Laboratory Manual

Central to the Bristol ChemLabS project has been the development of an interactive on-line Dynamic Laboratory Manual that helps students prepare thoroughly before each practical session. The Dynamic Laboratory Manual includes background information as well as formative and summative assessments to help students develop an understanding of the chemistry that they will be studying. In addition, video clips and simulations allow students to observe and practice the techniques that they will be using. Virtual instruments also give students the

confidence to use sophisticated equipment. A demonstration version of the Dynamic Laboratory Manual is available on-line at **http://newmole.chm.bris.ac.uk/dlm-demo17a/**

The developments have allowed a change in both the method and balance of assessment. Since students are now better prepared for their practical sessions, it is possible to perform more assessment face-to-face within the laboratory. As a result, students are no longer required to produce long write ups following each experiment. Instead, the skill of scientific writing is addressed through a purpose-designed course. Students are assessed on their achievement within the laboratory and the quality of their practical skills rather than on their report. This approach is not only a more efficient, but also a more effective method of assessment. As a consequence, students and staff enjoy practical classes more and benefit from the ability to focus on the practical work itself.

Although the Bristol ChemLabS project focuses on the teaching of chemistry, many of the innovations that have been introduced are applicable to practical teaching in other scientific disciplines including the biosciences.

5.2.1. Discussion and comments arising from the BristolChemLabS presentations

- There was much discussion about the funding support and the cost of what had been achieved at Bristol. Other universities were not in a position to make such a capital investment, or perhaps had other priorities. However, it was clear the Bristol achievement was not an all-or-nothing situation and some elements of the innovations could be reproduced elsewhere at little cost.
- A number of attendees were taken with the idea of different staff members wearing distinctly coloured-laboratory coats as an aid to identification amongst large student cohorts. A number of universities including Glasgow and Manchester also operate such a system.
- There was interest in the development of the Dynamic Laboratory Manual. When prompted the majority of attendees said they would make use of it if a similar resource could be developed in the biosciences. Such a resource could allow students to make a more focussed use of their time and could potentially be pre-loaded with a bank of practicals if these were also compiled or developed.

5.3. Inquiry-based learning in a first year biology laboratory class

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Presentation summary; slides at www.bioscience.heacademy.ac.uk/events/themes/practicals.aspx

This University-funded project introduced an inquiry-based laboratory class into a core 1st year Molecular Biology module, and aimed:

- to introduce students to the process of science at an early stage in their careers
- to teach students, through experience, about the scientific method, thus promoting active learning, and critical, analytical thinking
- to encourage small group work and collaborative-learning.

In the original module the practicals had been designed to complement the lecture material. Hence, students practice thin layer and ion-exchange chromatography when learning about proteins; carry out DNA transformation of *E. coli* and gel electrophoresis when studying the molecular biology of nucleic acids and genetic engineering; and search biological sequence databases using BLAST techniques when learning about bioinformatics. In 2006/2007 staff introduced a new practical designed to build on and develop the students' laboratory skills by getting them to design, conduct and trouble-shoot their own experiments.

The new practical was based on material from the successful 'Red and White Yeast' laboratory class developed in the US (White, 1999) [17]. Students are presented with a problem (the presence of red *vs.* white yeast) and work in small groups to formulate hypotheses, devise experiments, and modify successive experiments to work out the answer.

White's schedule was adapted to be suitable for the timetable and experience of first year biologists at St Andrews. The classes were arranged over 3 weeks, with the introduction of the 'yeast problem' to students in week 1, and subsequent weeks being spent designing and performing experiments to test their hypotheses.

A number of different learning styles were used to facilitate these processes: didactic teaching of the theory behind the 'scientific method'; small group discussion of questions and scenarios (facilitated by a postgraduate demonstrator or peer-led); students sharing their ideas, paths of inquiry and problems on the board; and large group discussions, led by staff. The goal was to develop an active learning strategy – promoting critical thinking, problem solving, intellectual debate and creativity. Also, to find out students' perceptions of science, scientists, and their expectations and preferences with regards to university practical classes, they were asked to fill out 'pre-practical' questionnaires.

Students were not marked on 'getting good results' but on the way they tackled the problem. The laboratory paper was split into 3 parts: a) Experiments: A Scientific Argument, b) Scientific Controversy and c) The Big Picture: What would you do next?

A paper by the physicist Richard Feynman called 'Cargo Cult Science' (1974) [18] was incorporated in Part C. Having described the experiments they would have carried out had time allowed, students were asked further questions, to encourage them to reflect on their experience:

- from your reading of the Feynman paper, what do you think is meant by 'pseudoscience'?
- pick either quote below, and write 100-200 words in response (supporting, disagreeing with, or applying it).

Scientists ought to have *"a kind of scientific integrity, a principle of scientific thought that corresponds to an utter honesty…. [I]f you are doing an experiment you should report everything that you think might make it invalid."*

"The first principle is that you must not fool yourself – and you are the easiest person to fool. So you have to be careful about that."

Following their exposure to active inquiry students completed a second questionnaire to determine whether their attitudes had changed and to inform future development of the module. For example, in terms of their **perceptions of science** more students identified science as 'controversial' and 'confusing', and fewer students identified science as 'exciting', 'detailed' and 'intuitive'. In terms of their **beliefs in science** fewer students agreed science 'proceeds logically'.

5.3.1. Comments and discussion arising from the inquiry-based learning presentation

- The above approach is good. The important element is not experimental results but the debrief when staff and students discuss what happens when things do not go to plan. This approach involves significant resource commitment and needs scheduled time after the practical has ended.
- Variations on the red and white yeast laboratory were discussed, such as exploring the phenomenon of antibiotic resistance, recreating 'Fleming's plate' or something similar i.e. fungus inhibiting growth of bacterium on a plate (or vice versa).
- Suggestions as to how much freedom to give students, with regards to access to chemicals and equipment were given.
- Good student engagement with this exercise is likely but the assessment may be counterproductive by turning an enjoyable activity into something students have to succeed at. Assessing students on how they tackled the problem might increase student anxiety if they are less able to determine how to score highly.

6. Group activity – redesigning practicals (in discipline groups)

Attendees were assigned to discipline based groups of 4-6 members with particular experience in a discipline or a closely related area (for list, see Appendix A). Groups were asked to address three issues with respect to their discipline:

1. important/priority learning objectives for 1st year practicals
2. five characteristics of engaging and effective practicals in 1st year
3. examples of 'bad' practicals and ways in which they could be improved.

6.1. Important/priority learning objectives for 1st year practicals

Each group was asked to define, within the context of their discipline, the five most important learning objectives of practical work for 1st year students. The learning objectives from the five groups are shown in Table 2.

From the data in Table 2 it is clear that disciplines do have some different priorities for the learning they expect of 1st year students. 'Handling micro-organisms safely' and 'identification skills' are obviously related to Microbiology and Field Biology particularly but with these exceptions the remainder of learning objectives identified were remarkably common to the different disciplines though the words used to express them differed. These common elements could be grouped into 6 broad areas as below as indicated by the letters in Table 2.

- **A.** Personal (confidence, engagement, reflection)
- **B.** Skills and competence in practical work
- **C.** Records and data (laboratory records, data collection and handling)
- **D.** Safety
- **E.** Scientific method as applied to problem solving and experimental design
- **F.** Clarification/illustration of theoretical concepts.

The extent to which these are delivered in each practical class, or should be an integrated outcome of the totality of 1st year practical experience, is open to discussion.

Table 2. Important/priority learning objectives for practical work with 1st year students

	Biochemistry	Field biology	Microbiology	Pharmacology	Biomedical Science
1	Confidence (laboratory, personal and social) **A**	Observation skills **B**	Handling microorganisms safely **B,D**	Developing equipment handling skills **B**	Employ scientific method to solve a problem **E**
2	Competence (equipment, skills, data analysis) **B**	Identification skills **B**	Exploration of microbial diversity **F**	Developing scientific method **E**	Record and interpret data **C**
3	Records - laboratory book **C**	Framing questions **E**	Engagement: the 'WOW' factor **A**	Understanding discipline concepts **F**	Discuss theory in context of the experiment **F**
4	Scientific method - hypothesis testing/ generation **E**	Group work skills **A**	Relevance – real-world applications	Data handling and presentation **C**	Use of equipment and techniques **B**
5	Safety – working to Health and Safety standards **D**	Experimental design **E**	Enquiry-based learning **E**	Data interpretation **C**	Reflect on what has been learnt **A**

6.2. Five characteristics of engaging and effective 1st year practicals

Each group was asked to define within the context of their discipline the five most important characteristics of a practical in order to make it effective and engaging for 1st year students. Some groups concentrated on issues which they believed would make a practical of high interest (and therefore effective and engaging). The results are shown in Table 3 in priority order.

It is interesting to compare the **TEACHER-generated** characteristics of engaging and effective practicals shown in Table 3 with those **STUDENT-generated** positive characteristics of laboratory work as defined in the UK and the US surveys reported earlier. In the UK survey, students identified as the best features of laboratory classes:

- **a.** learning new skills and using new equipment
- **b.** the opportunity for social interaction with students and teachers
- **c.** the function of practicals to illustrate material given in lectures
- **d.** the acquisition of new knowledge through practical classes
- **e.** high interest value of practicals.

Students identified as the worst features of laboratory classes:

- **f.** the length of practicals
- **g.** the poor organisation
- **h.** the associated write-up
- **i.** the tedious/boring/repetitive nature of practicals
- **j.** the variable contribution of staff.

These **student-generated** characteristics have been mapped to the teacher-generated ones using the corresponding letter code (Table 3).

Table 3. Most important characteristics of a practical to engage 1st year students

	Biochemistry	Field biology	Microbiology	Pharmacology	Biomedical Science
1	Context - relevance to engage and excite	Working with real plants/animals	WOW factor **e**	Fun, enthusing **e**	Creative
2	Experience of discovery **a, d**	Student ownership of the project	Relevant – clear application	Hands-on **a**	Relevant
3	Incorporation of IT	Getting into the field (real Bioscience)	Achievable within the time **g**	Well organised and supported **g, j**	Interactive/ hands-on **a**
4	Balanced curriculum – a different learning experience to lectures – overall relevance evident	Social interaction, group work **b**	Delivers results	Cost effective	Well organised **g, j**
5	Trained and enthusiastic support–staff (including demonstrators & technicians) **g, j**	Sense of achievement	Challenging	Fulfils learning objectives	Well supported **g, j**

The small number of mappings and the fact some of the characteristics which were high priority for students were not mentioned at all by staff (e.g. the length of laboratory work and opportunities for social interaction being prime examples) suggests there may be major differences between what staff and students regard as important characteristics of engaging practicals. Nevertheless, if we wish to enthuse, interest and involve students in laboratory work we should perhaps consider more carefully what students, as opposed to staff, regard as important.

6.3. Examples of 'bad' practicals and ways in which they could be improved

Each group was asked to describe a practical class they knew to be unpopular with students and to pick out the features which they thought made it unpopular. The group was also asked to define what changes could be made to improve the practical and what the constraints were on making them. It is instructive to compare the features identified by staff as making the practical/laboratory work unpopular with those features which students regard as 'bad' aspects of practical/laboratory classes. It is striking there is little congruence between the issues identified by the two groups.

6.3.1. Biochemistry

The biochemistry group chose an enzyme kinetics practical, which is a common practical in biochemistry units and is typically unpopular with students.

Bad feature	Possible improvement
Students arrive unprepared	Required pre-class reading and preparation
Initial talk to introduce class cannot be heard or lecturer seen because of large laboratory, support pillars, laboratory shape	Deliver as pre-class material or on local PCs or video monitors
Equipment out of date or not working and different models used in same class	Standardise on current equipment where possible and test it is working before the laboratory class
Long (20 page) photocopied handout from which to work	Essential practical instruction only; relationship to theory explained elsewhere or promoted by Q/A
Equipment/preparations set up already	Involve students in the preparation of the class and consideration of the implications of time constraints
Any attire/attitude accepted	Professional expectations should be made clear from the start
Any group size >3	Issue of group size and formation needs exploration
Staff (academic and demonstrators) don't understand practical and are uninterested	Require training for all staff and select suitable staff rather than taking whoever is available
Staff have poor communication skills and are running the practical not teaching	Training of suitable staff required; additional support staff to reduce organisational burden
Enzyme preparation old, effectiveness not tested	Work with new material and establish effectiveness immediately before practical
Cramped benches	New laboratories or duplicate practical class
Excessive pipetting mandatory	Redesign to a limited extent – pipetting is a valuable skill!
Data must be perfect, no repeats	Provide a simulation so data can be generated for failed experiment or allow repetition of laboratory exercise until student satisfied with data Shift emphasis to sources of error rather than perfect results

Constraints which may make the introduction of proposed improvements difficult:

- lack of **funding** for new equipment (this impacts group size)
- **timetabling/teaching loads** and related staffing issues
- introduction of pre-laboratory work requires **agreement of course coordinators**.

6.3.1.1. Discussion

One of the key issues is setting the scene – providing a suitable context enhances interest and motivation. The practical should allow at least a degree of discovery and experimental design. If it is likely the equipment may fail

students should not be assessed on the final result which would discourage a 'have a go' attitude; instead encourage them to get stuck in – if it does not work – repeat if there is time and/or think about the 'why?'.

Staff attitudes undoubtedly affect students so it is essential, especially in first year, that students encounter enthusiastic staff (and postgraduate demonstrators). Possibly, suitable staff could be trained as specialist practical teachers but current reward mechanisms may not encourage this.

The University of Glasgow has a dedicated team of laboratory leaders who are familiar with the practical content, are enthusiastic and have been instrumental in development of laboratory materials. They convey enthusiasm to students, who know they have a support structure within the laboratories to allow them to work with their peers but ask for help when needed. Staff keep an eye on students, intervening only when necessary. The demonstrators are also invaluable in conveying enthusiasm. Demonstrator ability varies but the best are outstanding. Students will quickly learn to avoid a weak or uninterested demonstrator waiting until another demonstrator or laboratory leader becomes available.

To improve student contact with research active staff, lecturers and others are encouraged to come to laboratories associated with their field of biology and act as "experts". Such staff are invited to demonstrator training meetings – those who then attend the class are a real asset, and have been known to influence a student's choice of degree (Glasgow operates a Faculty entry system). Similarly, the University of Manchester has a specific course plus on-the-job training for each experiment.

Enthusing students encourages them to prepare for laboratory classes – it is a slow process, but compulsory pre-classes could be counter-productive. Formative assessment with questions and answers and including marks for practical completion motivates students to a) attend and b) read essential information.

The issue of group *vs.* individual working might be solved by shorter practicals with smaller groups.

If we give students 'perfect' data how can we expect them to come to terms with the fact that most of their data collection in real situations will not be perfect? Isn't it preferable to let them find out data is not always cut and dried, that things go wrong, and often, the interest is in working out if the data is significant, or if the experiment needs a rethink, or how to explain anomalies? By presenting students with 'perfect' data we encourage acceptance at face value not a questioning approach.

6.3.2. Field Biology

The field biology group chose a field work practical involving comparing vegetation and fauna in a range of woodland types, incorporating a visit to a wood and observation of the environment.

Bad feature	Possible improvement
University terms not conducive to observational field work	Flexible timetabling, during summer term; field courses during summer vacation
Staff and students not bio–literate	Prepare students in house. Build a trainer facility in house; e.g. teaching aids to teach identification skills, e.g. birds, birdsong, plant slides Test with quizzes and through practical experience
Can't compete with nature TV which brings together observations over long time periods	Design a TV film; build a virtual environment
Travel time constraints	Identify and use local field sites and resources
Risk, safety, appropriately clad students	Require professional standards and behaviours from the start
Real life is more complex than standard texts	Provide non-idealised teaching materials to contrast with standard idealised descriptions

Constraints which may make the introduction of proposed improvements difficult:

- **group size**. It is often difficult to find field sites that can support large groups of students. Breaking groups up to repeat sessions is not efficient. Reducing staff : student ratios by increasing the numbers of staff/demonstrators available is expensive (if suitable persons are available). One strategy (variants of which have been used with some success at the University of Hull and Newcastle University) is to hand over responsibility for the visit to students - smaller student groups select their own sites and make unaccompanied visits, working to a well-planned practical schedule. This frees staff to concentrate on preparation and debriefing (that can often be done with larger groups) and minimises impacts upon single sites. It promotes autonomy of learning, but generates issues related to risks, transport and variations in student motivation.
- **availability of equipment**. Specialist field equipment can be expensive and is often difficult to store
- the **complexity of reality**. Text books and pre-university tuition often present idealised scenarios in field ecology (regular bands of animals and plants horizontally arranged down a rocky shore being a classic example). Real sites therefore rarely match the expectations of the student. It is a mistake to try to fit the site to the expectation – rather, advantage should be made of this perceived anomaly. Students should be encouraged to evaluate the value of the generalised model and to explain the miss-match that is observed. This negative can and should therefore become a positive.

6.3.3. Microbiology

The microbiology group chose a practical involving the essential skill of counting bacteria. The practical involves making serial 1:10 dilutions, plating a known volume of the dilutions, incubating for 48 hours and then counting the colonies and calculating the number of bacteria per ml of the original undiluted sample.

Bad feature	Possible improvement
Boring, involving repetitive dilutions and pipetting. Students need to concentrate to perform correctly.	Introduce a system involving moving tubes in racks during dispensing to avoid errors Award prizes for most accurate answer; grade marks according to accuracy of results
WOW factor negative! Low tech, no exciting kit in use	Enquiry-based: build an investigative scenario, use group experiment and set the whole class the problem to solve Work individually and mark on accuracy of results Prize for best results (as above) Introduce state-of-the-art pipetting devices, perhaps one per group, so students are at least aware of high-tech. equipment and how it can be used
Relevance to real life not obvious	Use real samples - soil, water, milk – build a scenario (dirty hospitals, food-poisoning outbreak, testing bottled waters from different makers)
Delay (during incubation) between practical and getting results	Provide mock data to work with while own samples are incubating
Long write-ups usually involved	Use more appropriate assessment (i.e. of practical/laboratory skills, calculations and results)

Constraints which may make the introduction of proposed improvements difficult:

- bridging the gap between the **ability of demonstrators to teach** dilutions and the problems students have in understanding the issues
- potential **exposure of students to pathogenic organisms** (consider sources of samples carefully).

6.3.3.1. Discussion

Practical exercises based on dilutions are a necessary evil for microbiologists, given the very large numbers of organisms found in many microbial samples. Many students can work through dilution exercises without problems but a significant minority of students have problems getting their heads around the concept of serial dilutions. For these, it is important to provide follow-up support materials; for examples see: www.bmb.leeds.ac.uk/mbiology/ug/ugteach/bmsc1213/Micro/Micro_2/player.html and www.bioscience.heacademy.ac.uk/ftp/resources/ibflash/dilutionseries.swf

Practicals involving pipetting can easily be made more interesting by incorporating real life scenarios e.g. determination of the concentration of a toxin used to lyse red blood cells (in reality soap) engages students and does add some "wow". A small proportion of total module marks should be awarded for this exercise and the skill should be 'reinforced' by introducing a similar exercise at a later stage in the module.

An alternative solution to providing mock data to occupy students during incubation periods could be to split the practical and have one session in the morning say 9-10am and another 2-3pm to read the results.

6.3.4. Pharmacology

The pharmacology group chose a practical utilising a standard technique in pharmacology involving an isolated piece of guinea-pig ileum and the determination of the dissociation constant of an antagonist (often expressed as a pA_2 value) as determined from an Arunlakshana-Schild plot. This involves determining several dose-response curves to an agonist in the presence of various concentrations of an antagonist.

Bad feature	Possible improvement
Students arrive unprepared	Handouts before practical; compulsory use of a simulation before coming to the laboratory class
Short but complicated lecture given at start	Schedule practical after material presented in lecture
Easy to make a mistake by adding the wrong dose at the wrong moment	Shorten experiment and confine to one control curve and one in presence of each concentration of antagonist
50 students - 5 per organ bath set up	Duplicate class and have students work in pairs; OR give students the choice of a wet laboratory or a simulation
Tissues set up prior to start of session	Students set up own tissue
Equipment often fails	Test before experiment
1 academic unfamiliar with the experiment and an unpaid demonstrator	Adequate training provided and appropriate staff available
Long experiment involving repetitive dosing and washing of the tissue	Reduce to control curve and a single repetition in the presence of two different antagonist concentrations
Assessed by 'Short Essay on Schild Theory'	Assess on accuracy of result and quality of data
Boring experiment	Put into 'unknown new compound' scenario Award prize on accuracy of data
Long experiment	Work as a class – each group to produce one dose ratio and do a combined class Schild plot

Constraints which may make the introduction of proposed improvements difficult:

- timetabling
- availability of staff and demonstrators.

6.3.5. Biomedical Science and Physiology

The biomedical science group chose a practical involving a microscopical examination of a section of liver and of a monocot plant stem.

Bad feature	Possible improvement
Dull no buzz in the laboratory, students not interested	Allow students to select tissue to be used from a pool to provide relevance for them (e.g. pathology - diabetic pancreas; forensic - identification of tissue as animal/human)
No enquiry base, purely an exercise	Introduce enquiry–based work by setting mystery scenario – e.g. identify different cell types
Relevance; not obvious why this task is being set or why it is necessary	Explain importance of skill of microscope use
Comes some time after related lectures	Locate close to lectures or convert the lecture to a pre-laboratory session (see below)
Students unprepared to use microscopes	Pre-laboratory work: video on how to use microscopes available and required pre-class use of the VLE
Learning objectives of practical not clear (set up microscope; scientific drawing and labelling, EMS & light microscope use).	When planning practical, check learning outcomes fit with practical learning outcomes for the programme Clarify and define learning objectives to students
	Use peer assessment & feedback to assess output; teach critical appraisal of others' work
	Improve socialisation by introducing peer assessment

Constraints which may make the introduction of proposed improvements difficult:

- availability of technical help and appropriately-trained demonstrators
- lack of resources including the availability of suitable tissue material
- lack of preparation time.

6.3.5.1. Discussion

Some of the constraints discussed in relation to implementing these changes were related to the cost in terms of time investment and possibly funding. However, the benefits gained by improving the practical in this way would outweigh any costs that might be realistically incurred and the member of staff in charge of the practical plans to use suggestions from the group to make improvements to the exercise in time for the next academic year.

The introduction of peer assessment is suggested above as a potential improvement but one person commented: the introduction is load intensive and may lead to a deterioration of socialization if the groups fall out; this should be avoidable given careful management.

6.3.6. General discussion and conclusions

A number of pointers came out of this section of the workshop:

- staff were able to identify bad features of laboratory classes and to demonstrate these were not inherent in the class itself but could be changed
- there is clearly no shortage of creativity amongst bioscience teachers. Those present demonstrated an ability to think innovatively and to come up with ideas for changes to laboratory classes which would very likely improve the student experience
- participants were clear there is need to re-invigorate practical teaching but it is not clear where the drive for this will originate. HUBS, the Biosciences Federation, the Institute of Biology and the Centre for Bioscience could all play an important role in bringing this issue to the fore and motivating teachers to make the necessary changes
- there were some disparities in the features identified by staff and those of concern to students. Staff should perhaps be viewing things more from the student perspective if we wish to make an impact on student perceptions of 1st year laboratory classes
- while staff were able to identify 'bad' aspects of practicals, a reasonable question in the light of this is 'Why had these bad aspects been allowed to continue?". It is important to note the constraints which are in operation. Are the major constraints staff time, resources, laboratory space, staff reward or something else? Is it simply that what makes a good laboratory class from staff and student perspectives has not been clearly surfaced before with many bioscience teachers? To get interesting and exciting practicals do we need to get enthusiastic and excited staff to put into practice the creativity we saw at the workshop? Why should busy staff spend the time reinvigorating practicals when their performance is measured against other criteria?

For further background on inquiry-based laboratory classes readers are directed towards *Un-cooking the Lab: A Guide to Constructing Inquiry-based Labs in Biology* [19], and references therein.

7. Examples of good practicals

7.1. Principles of design illustrated in the contributed practicals

Each discipline group was asked to produce an outline of a practical. Some additional examples have also been contributed by individuals – all can be found in Appendix B (pages 28 to 39).

It is important to understand how these examples may best be used. You may be lucky and find the examples include a laboratory class matching your needs but this is unlikely. Ideally, teachers will read all the outline practicals regardless of discipline, and take from them the ideas and approaches which are applicable to their discipline and circumstances and which would improve the practical classes delivered. To this end email contacts have been provided so expansion of the relatively brief information given can be obtained.

For those wishing a more focussed less time-consuming approach the innovative ideas and concepts illustrated in the various example practicals have been compiled in Table 4. Thus if you are particularly interested in the use of pre-laboratory exercises Table 4 will point you to appropriate examples where these have been used.

Table 4. Particularly innovative and interesting aspects of example practicals

Attribute	Found in practical number:- -									
	1	2	3	4	5	6	7	8	9	10
Context in which the class is important			x	x		x				
Use of compulsory pre-laboratory work			x	x		x		x	x	x
IT delivered pre-laboratory exercise									x	
Use of simulation									x	x
Provision of choice (options)			x				x		x	
Use of discovery methods		x					x			
Problem-solving		x	x	x	x	x				
Innovative write up									x	x
Social interaction promoted			x							
Organisation innovations									x	
Introduction of excitement						x		x		
Complements lectures/reinforces learning	x	x		x				x		
Challenging			x							
Elements of self-design of work			x							
Integrated with other practicals		x								x
Extended over several timetabled sessions			x				x			
Linked to post-practical activity	x	x						x		x
Use of class pooled data		x								
Assessment by non-standard write-up			x	x					x	

8. Closing comments (Martin Todd, AstraZeneca Pharmaceuticals)

The teaching of practical skills in the Biosciences at the undergraduate level is becoming more challenging due to a number of factors: increased student numbers; increased costs; reduced funding; retirement of experienced staff. Bioscience is a practical subject where it is important to understand scientific hypotheses, experimental design and data collection, statistics, biological variation and effective communication. It is important for students in the early stage of their courses to understand the challenge and the excitement of making observations on biological systems whether they plan to continue in Bioscience as a career or not. As employers we seek people who are interested in the subject and have an appreciation of the value of experiments in Biology as well an understanding of the use of equipment and the handling of biological samples. A problem-based or investigative approach within practical classes is most likely to exemplify the types of situations young people will find in experimental biology if they choose a career in academia or industry. An attractive and interesting experience in practical biology early in the undergraduate course offers the prospects for interesting students in continuing their education within practical Bioscience.

There is an opportunity for the development of good practice in this area which will be engaging to students, interesting to faculty and of value to the Bioscience community as a whole. The various stakeholders: faculty, university administrators, university funding bodies, scientific societies and employers need to be involved so that there is a coordination of this activity to deliver high quality practical classes and the appropriate funding to support this activity.

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Slides presented during the workshop, additional materials and a downloadable (pdf) version of this report are available from: www.bioscience.heacademy.ac.uk/events/themes/practicals.aspx

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Appendices

Appendix A – Discipline groups

Group 1 – Biochemistry
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Carol Wakeford
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Group 2 – Field Biology
Richard Bevan
Maria Chamberlain
Julian Park
Graham Scott
Anne Smith

Group 3 – Microbiology
David Adams
John Heritage
Ken Hudson
Julie Rattray
Helen Smalley
Joanna Verran

Group 4 – Pharmacology
Steve Arkle
Gabriel Boachie-Ansah
Alan Gibson
Mike Hollingsworth
Martin Todd

Group 5 – Biomedical Science
Mike Hayes
Helen Hooper
Nigel Lindsey
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Appendix B – Examples of good practicals

B1. Biochemistry

Compiled on behalf of the group by Darren Gowers (Darren.Gowers@port.ac.uk)

At some point during their first year, most biochemistry students encounter (or collide) with the topic of enzyme catalysis. For some the reaction is fruitful, while others can be left with a rather poor affinity for the subject. Enzymology practicals are many and various across university bioscience departments, ranging from short and simple to long and involved. Many have an illustrious history, handed down like heirlooms simply because 'they work'; many also have an illustrious photocopying record. Certainly redesigning one or more practicals is a lot more effort than updating a lecture slide.
We share here two practicals from different universities that are currently in use for 1st year undergraduates. Part 1) below gives a brief overview of each practical class, whilst Part 2) looks at aspects of their pedagogy.

1) Overview of two practicals

The two practicals are described only in brief here, but can be found in full at www.bioscience.heacademy.ac.uk/events/themes/practicals.aspx

Practical 1: The kinetics of acid phosphatase (originates from University of Portsmouth; Darren.Gowers@port.ac.uk)

Context
This is a Level 1 practical taken in the second semester by a total of around 100 students in class sizes of 30. It comes after a series of lectures on protein structure and catalysis, and has a post-practical workshop tied to it.

Aims
To put into practice students understanding of enzyme kinetics. To do this, they measure the initial reaction rate of the enzyme Acid Phosphatase at various concentrations of its substrate PNPP, and determine accurate values for the enzyme's V_{max} , K_m , k_{cat} and k_{cat}/K_m.

Learning objectives for students:

- to learn how to prepare timecourses and take accurate timepoints
- to practice handling enzymes, and understand why they need buffers and cofactors
- to practice pipetting and using common laboratory equipment such as a spectrophotometer
- to inspect data, plot it, and calculate initial rates of reaction from a linear fit
- to determine parameters of the reaction, including V_{max} and K_m.

Practical 2: Artificial suntan… or brown bananas! (originates from the University of Manchester; carol.wakeford@manchester.ac.uk)

Context
This is a Level 1 practical that precedes an assessed practical on enzyme kinetics (Determination of K_m and V_{max}). It is part of a stand-alone Semester 2 skills-based practical unit. Students have already learned how to use spectrophotometers and are familiar with the Beer-Lambert Law.

Aims
To introduce students to the concepts of speeding up chemical reactions with enzymes and the measurement of reaction rate as the initial rate of product formation.

Learning objectives for students:

- to design a simple experiment to produce dopachrome
- to prepare a crude extract of the enzyme tyrosinase from banana by homogenisation and centrifugation
- to identify the reaction product dopachrome from it's absorbance spectrum
- to monitor, record and calculate (as $\Delta A\ min^{-1}$) an initial rate of reaction using a spectrophotometer and printer
- to calculate the initial rate (in $\mu mol\ min^{-1}$) of the oxidation in air of L-DOPA to dopachrome from the increase in absorbance with time using the Beer-Lambert Law.

2) Aspects of teaching and learning

For simplicity, these are grouped into activities that generally take place before, during or after the practicals.

Before

Provide the students with plenty of lead-time to prepare. Practical 1 is provided to students online well before the practical day. It is tied closely to the end of a lecture sequence on enzymes, and this works well, since the preceding lecture is used to remind students to get printing and reading. Practicals in this unit are never allowed to 'float' in the timetable, ensuring a practical always follows a specific teaching block, which students find logical. Practical 2 is part of an independently running practical unit, which is a very helpful idea for engaging students more meaningfully with laboratory and field work. Practical 2 is also a 'warm-up' practical before an assessed one the following week. This approach, when the pressure is lower, seems a good way of giving students more confidence to learn (often by mistakes) in the laboratory. The idea of having a 'scenario' or recognisable context for the experiment (as in Practical 2) will help students feel the relevance of their work.

During

Practical 2 contains an element of experimental design, which is a very powerful way of helping the students to think and question their understanding. Students respond well to this problem-solving approach, and this works well at Level 1. Practical 1 is representative of the 'old fashioned' recipe-type practical, but has been re-written extensively from that inherited by the author.

Both practicals have in fact very many similarities in the anticipated student learning: using equipment competently, measuring rates and calculating parameters. Both have enzyme-substrate systems that work very reliably. (Which is obvious, but crucial – use forgiving enzymes that do not denature too readily and will stand some degree of rough-handling).

Simple equipment works well. Both practicals use a spectrophotometer to measure a change in substrate absorbance, and Level 1 students must learn how to use these at some stage. It may be possible to use any dead-time in the practical to do some teaching, or even another activity such as taking an old spectrophotometer apart for budding engineers etc!

Both these practicals are easily <3hrs running time, and run smoothly with the help of technicians. Excessively long practicals (>4hrs) may not be so helpful for meaningful (and cheerful) learning.

Teacher : student ratio. Class sizes vary widely between institutions, but a ratio of approximately 1 academic per 20/30 students is about average in these classes. Demonstrators must be trained, paid and helpful. Can they practice prior to it starting?

Making mistakes is immensely beneficial to the learning process. One might even argue that we should design-in certain 'challenges/flaws' that students have to negotiate, in order to help them understand certain procedures. For example – "carry out the reaction at 80°C. What happens to the rate?" Even better is having enough time to be able to repeat parts of the practical again if necessary, should they make a mistake.

Formative assessment is used in Practical 2, summative assessment in Practical 1. In both though, face-to-face feedback and questioning is used, which most students respond to well. The write-up for practical one is as short as possible, with a simple marking scheme to keep marking time down for lecturers. Ideally one can mark there and then in a practical (which we do in other of our units), with the benefit of immediate feedback on their grade.

After
Use a workshop? After Practical 1, the next day's session is a workshop, in which the students have time to go at their own pace through the method and results of the practical again. This was started when we recognised that a practical is actually longer than just the session spent in the laboratory. Students often have questions that arise as they work through the write-up. It is also useful for students to look at the laboratory data collectively, and work out how they could have improved their technique (or indeed the design of the practical).

Pooling class results. This can be helpful for giving students a sense of experimental error, and how to weed datasets prior to analysis. [Or, more variables can be introduced to the experiment, such as the effect of temperature, pH or enzyme mutation, to give a wider picture of enzyme activity. This may be more suitable though for Level 2 or 3?].

The skills acquired in Practical 2 are put to immediate use in a follow-up, assessed practical on yeast alcohol dehydrogenase, which students invariably enjoy because they are confident with the methods and competent at the calculations.

B2. Field Biology

Practical 3: Design a TV nature documentary
Compiled by V Anne Smith on behalf of the group (anne.smith@st-andrews.ac.uk)

Background
In this practical, students are expected to design a TV nature documentary surrounding a particular environmental or ecological subject, in the style of something they might see in a programme such as Horizon or by David Attenborough. The concept of this practical follows the idea of "learning by teaching", where, by being required to present the material such that it would be understood by a general educated audience, they have to think through and solidify their own understanding. Additionally, they learn about field techniques by planning and justifying the practical elements that would be necessary to produce such a film. The students are encouraged to make their documentary interesting – not just a film version of a textbook – by presenting a particular angle or story, for example, following a particular animal's or plant's life, presenting the "story of a day" or "story of a year", following researchers through a field season, or any other original idea.

Learning objectives

Students are expected to:
1. identify a local habitat or species for further study
2. review background literature to the above
3. outline the objectives of their proposed documentary
4. complete observational field visits, compile field notes and take photographs
5. complete a "storyboard" which should contain written commentary and examples of the photographic material that would be needed to support the storyboard (*i.e.* example photographs, sketches or diagrams).

The assessed output of the practical is the storyboard of the documentary, including all narration and interview text, and a list/description of the resources and fieldwork techniques required to accomplish the film. Students work in groups and are told their documentaries should be aimed at 15 minutes in length, with the guideline that typical narration occurs at the rate of 125 words per minute.

Examples of themes for investigation include:
- evidence of large mammal activity in local habitats
- day in the life a specific species
- primary succession on reclaimed land/newly dug soil/mine waste
- invasive aliens in local habitats
- reed beds or other restoration ecology projects in the local area
- the ecological value of urban rivers and streams
- effect of freshwater inlet on foreshore ecology

- common wetland plant species
- wading birds on tidal mud flats
- the tidal cycle
- the emergence of woodland flowers in spring
- invertebrates in leaf litter from different trees
- forest regeneration
- community woodlands.

Exact topics depend on issues related to local area and field sites available. For larger classes/more distant field sites, the class can be divided into different types of field sites and topics distributed appropriately.

Suggested structure of the activity

Session 1: Students asked to form groups and are introduced to the task with example storyboards from real programmes. Short video clips shown from archives. Students are provided with a list of suitable local field sites (which they will visit independently or be taken to as a group). Students determine how they will divide up the work roles within their group, and elect a "director".

Session 2: Students visit sites to make observations, sketches and take photos, etc. Students work in their groups to identify the topic of their documentary.

Session 3: A second site visit to allow students to collect images, etc. and refine their views/ideas.

Students are asked to complete individual storyboards to be presented two weeks after field visit in week 3. This could be done in their own time or as part of a tutor facilitated session in the presence of their peers, thereby allowing formative feedback.

Session 4: Students present their storyboard and provide an account of the way in which the documentary would be made to the class for assessment/discussion.

This practical incorporates all of the characteristics identified as those that increase student interest in field biology practicals. The students work with whole organisms in the field.
The students use their own originality in the production of a concrete product, a documentary design, which will provide them with both a sense of ownership and achievement. Finally, the work occurs in the context of a social group.

This practical addresses a number of learning objectives identified as important in field biology practicals. The students will need to use and develop observation and identification skills while scouting field sites, to find and identify organisms and other features of the ecosystem to be featured in their documentary. They will develop group work skills to coordinate and perform the work in this practical. Finally, depending on the subject matter, students may also be required to frame questions and design experiments for their documentaries.

This practical works to overcome some of the limitations identified as common in field biology practicals. In particular, this practical directly addresses the issue that field experiences cannot compete with the level of visuals presented in TV nature programmes by taking advantage of students' enthusiasm for such programmes by asking them to design one. Additionally, as the students have to think about the resources and practical techniques required to produce such programs, the students will gain an understanding of the time and effort needed to produce the amazing visuals of a TV nature documentary. Similarly, the fact that nature is more complex and confusing than textbooks is turned into an advantage, by allowing the students to tell an interesting story surrounding the real situation they find in their field site. By making the students design, but not actually create, a nature documentary, the practical avoids issues regarding timing of the academic year, because students can include plans to film events that would occur at different times of year. Scouting field sites provides a concrete physical setting for the film, but students' imagination can be applied to plan scenes such as hatching of chicks, capture of prey, time-lapse growth of vegetation, etc. This property also allows choice of nearby field sites, which may not be optimal for actual observation, but adequate for scene-setting and extrapolation, and thus removes the need for long transportation times. Finally, the need to identify the organisms in their field site for the documentary will provide practice in identification skills.

Practical 4: Investigative project in Environmental Microbiology (devised by Dr Gordon Craig, Manchester Metropolitan University; J.Verran@mmu.ac.uk)

Background
This exercise takes place after the Easter vacation. Students have previously had 3 formal laboratory sessions where they have been taught: safe handling of microorganisms/aseptic technique, Gram stain, isolation plates, dilution series.
The project described below is therefore extending, applying and reinforcing these skills via a simple, yet more open, investigative activity.

Learning outcomes
At the end of the practical, students will be able to:

- design and conduct an investigation using basic microbiological techniques
- isolate, enumerate and identify bacteria or yeast from the environment.

Information provided for students (abbreviated)

Introduction
For this exercise you will take on the role of a microbiologist working for an environmental consultancy. Your task is to design and carry out an investigation for the isolation, estimation of viable numbers and presumptive identification of bacteria or yeast from environmental samples. You must provide a flow chart of how you intend to conduct your investigation, outlining the key steps and procedures.
Samples to be tested are: contaminated river water, spoiled milk, live beer, live yoghurt, soil and organic flour.
You will work in pairs.

Safety aspects
Consult 'Precautions for microbiological work' and the COSHH station. Wear correctly-fastened laboratory coat, eye protection and gloves as appropriate.

Method
Before the practical
Use the library, internet, practical schedule and other sources to research the methods you are going to use.
Produce a flow chart describing the procedures you plan to use (demonstrators will help).
Describe how you plan to record and analyse your results

Session one
Present prepared information to a demonstrator for assessment and approval.
Choose one liquid and one solid sample.
Carry out your experimental procedure to isolate and estimate viable numbers of bacteria or yeast in the two samples. Appropriate media are recommended.

Session two
Record results and calculate the viable number of bacteria or yeast in your sample. Select separate distinct colonies and carry out a presumptive identification (colony characteristics and Gram stain).

Assessment
Flowchart, 20%; outline for recording results, 10%; experimental skills (assessed in laboratory), 20%; and completion of results sheet provided (viable count calculation and statement of presumptive identification), 50%.

Concluding comments
There is potential to develop this activity into an extended and challenging piece of work. Subsequent to this workshop, Prof Verran and Dr Craig carried out an evaluation exercise on the practical. During the second (final) class, students were issued with a brief evaluation sheet asking 3 questions:

1. What did you like best about the exercise?
2. What did you like least about the exercise?
3. Is there anything we can do to make the exercise better in terms of helping your microbiology studies?

Approximately 80 replies were received. Although responses were free text, several themes were readily identifiable. Students 'liked' planning (8), working independently (11), and using skills that they had already been taught (28). They liked the 'practical' (11), Gram stain (18) and dilution (7). 'It was fun. I liked Gram staining and I felt like I was responsible enough to do the lab and it was individual work'. 'I liked the ability to go over all the techniques learnt through the year by ourselves'.

The 'didn't like' responses were far fewer. Microscopy (11), counting (10), and the 'smell' (4) are inevitable aspects of microbiology, but recording and reporting, and pooling class results (6), the overall speed of some procedures (3), and queuing for staining (4) could be improved in future. 'I didn't like everyone else's results'.

Suggestions for improvement were again relatively few, but useful. Requests for more guidance, reference reading and explanation from the teachers (12) could again relate to confusion encountered over recording and reporting results, noted above. One student suggested that results from 'previous projects' could be used for comparison with their own. Several (7) students asked for more work, a longer class, and suggested bringing in their own samples. 'Best lab this semester'.

These very positive comments clearly demonstrate that the students appreciated the opportunity to practice their microbiology techniques in an applied context, with minimal report writing, in a supportive environment.

Practical 5: A brilliant demonstration (from John Heritage, University of Leeds; mic6jh@leeds.ac.uk)

One very successful demonstration that we use at the University of Leeds is a demonstration of luminescent bacteria. It is very simple to organise, requiring only a darkroom that can accommodate small groups of students. We inoculate a number of glucose agar plates with cultures of *Vibrio phosphoreum*. We have a talented artist on our technical staff and students particularly like caricatures of the module manager in agar and bacteria. We use a range of other pictures, as well as traditional plating out. The incubated cultures are available for viewing. We also prepare a broth culture.

Students are taken into the darkroom and after a short period for eyes to adjust to the dark, plates are passed around and discussed. There are numerous points for discussion. Firstly, luminescence is greatest around the edge of colonies where glucose remains adequate. In older cultures, the luminescence can be, frankly disappointing, and in the centre of cultures, there is a diminution in shine. We use this to discuss the role of glucose in energy production and how nutrient media get depleted. The broth culture is then shaken to indicate the importance of oxygen to the process; this has the effect of turning on a light switch and has a tremendous WOW factor. We then explore the biology and other issues surrounding the phenomenon. Points for discussion include:

- the use of luciferase in assays for ATP
- the role of photobacteria as symbionts in fish
- the nature of mutual symbioses
- the role of photobacteria as food spoilage organisms, particularly of fish
- the use of *lux* as a reporter gene in genetic modification and gene expression experiments
- the possibility of self-illuminating Christmas trees
- the convergent evolution of light emission: fireflies have evolved their own light-emitting apparatus
- could photobacteria be used as an illumination system
- Lucifer - the brightest of the angels.

There is an excellent website for follow-up for interested students: www.biology.pl/bakterie_sw/index_en.html

Further details
The information provided for students in the module manual is available at www.bioscience.heacademy.ac.uk/events/themes/practicals.aspx. To place this in context, an outline of the course is provided as well. The demonstration is part of a rather light exercise on the effects of oxygen and temperature, undertaken in Week 5 and acts as a taster for the subsequent environmental microbiology exercise.

Practical 6: Food Microbiology practical – 'The incident' (Helen Smalley and Richard Sands, Liverpool John Moores University; H.B.Smalley@ljmu.ac.uk)

Background
This practical is from a Level 2 Food Microbiology module, though it would also be suitable for Microbiology students at Level 1. Students have previously been taught safe handling of microorganisms, aseptic technique and viable counting techniques. The practical is investigative and involves problem-solving. The scenario mimics a real-life situation and the procedures that would be carried out in a Food Microbiology laboratory. Students are given an important example of an application of the viable counting technique, which is sometimes perceived as repetitive and tedious.

Learning Outcomes
After the practical, students will be able to:

- perform viable counts on a food sample
- calculate the number of viable organisms in the food sample
- identify some of the bacteria present by Gram stain and growth characteristics on selective media.

Student preparation before the practical
This practical complements lectures about foodborne pathogens and methods for microbial examination of foods. Students should bring the article 'Guidelines for the microbiological quality of some ready-to-eat foods sampled at the point of sale' (www.hpa.org.uk/cdph/issues/CDPHVol3/no3/guides_micro.pdf) to the practical.

'THE INCIDENT'

Twelve passengers and one crew member (the Captain) suffered severe vomiting and diarrhoea during a transatlantic flight from Los Angeles to London. All the affected passengers were economy class and had eaten the main in-flight meal. The incubation time was estimated between 2-4 hours. The Captain was admitted into hospital in London.

Initial questions:

- is this a microbiological problem?
- is it food related?
- how did it get there?
- who else could be at risk?
- what are the consequences?

The task
Several food items have been recovered for bacteriology. You are asked to determine total viable counts (quantitative) and the identity of any possible pathogens (qualitative). Working in groups, select one of the seven food items. Carry out a TOTAL VIABLE COUNT and determine the presence (or absence) of any potential pathogens by inoculating the prepared plates to reveal single colonies (ask about this if you are unsure). We have not included the full range of specialist media and revival broth normally associated with a professional food laboratory. *We usually provide blood agar, mannitol salt agar, CLED and brilliant green and MacConkey agar.*

A - Hors D'oeuvres
B - Shrimp salad
C - Roast turkey *spiked with Staphylococcus aureus*
D - Egg flan
E - Salad dressing
F - Chocolate cake
G - Custard
In the past, these foods have provided a variety of isolates, but over the last two years, some students have been unable to isolate anything to investigate. It may be necessary to seek less high quality foods or spike the other foods as well. Also, we provide demonstrations of appropriate bacteria on the specialist media plates.

When all the plates have been inoculated leave clear instructions for incubation conditions. It is your responsibility to 'read' the plates after the appropriate incubation time.

For further details including the pour-plate and qualitative methods, and student handout see www.bioscience.heacademy.ac.uk/events/themes/practicals.aspx

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Practical 7: Experiments on microbial growth (Julie Rattray, Glasgow Caledonian University; j.rattray@gcal.ac.uk)

Subculturing and isolation exercise

These experiments will give you some experience of the basic aseptic techniques used in the cultivation of microorganisms. In addition, they will introduce you to some simple means of testing the properties of microorganisms to enable you to identify them.

Week 1

Each group of 4 students is provided with a set of unknown organisms growing as broth cultures. For each organism:

a) inoculate a tube of nutrient broth and inoculate an agar slope. Remember to label the cultures suitably. They will be incubated for you.
b) select a 'pet' organism and prepare a streak plate with the culture of your pet organism.

Week 2

Examine last week's cultures:

a) Examine each nutrient broth for evidence of growth.
b) If the broth is not turbid, the bacteria may have sedimented: suspend them by gently rotating the culture.
c) Examine each slope. You should be able to see some evidence of growth on the agar surface. Has the organism altered the slope in any other way e.g. by the production of pigment?

Make the following subcultures:

Use the slope culture as the source of inoculum throughout. If you are not sure that an organism has grown check with a demonstrator before using the culture. Label all plates clearly.

a) Prepare a streak plate of each organism.
b) Inoculate the following selective and differential media with each organism by quartering the plates: MacConkey, Blood agar, King, Ward and Raney's A, Mannitol salt agar.

Heat treatment test

This will be used to determine if any of the cultures has produced heat-resistant endospores. Use the broth culture of each organism but as before check with a demonstrator if in doubt about its growth.

a) Expose each culture to 80°C for 10 minutes in a water bath.
b) Take a nutrient agar plate, quarter and label it. Transfer a loopful of each heat-treated culture into the appropriate quarter of the plate. If any of the bacteria have survived the heat, they will appear as colonies after incubation.

Gram stain

If time permits, prepare a Gram film of each organism, using the slope culture. Either in this class or before the experiment is completed, you will need to examine the slide microscopically, draw the bacteria and give their Gram reaction. If you wish to have the slides stored you must label them clearly and hand them in.

Remember to put all plates in for incubation. Just in case one of your organisms does not grow, retain all your slope cultures: put them into the container to be refrigerated.

Week 3

Examination of cultures

a) For each organism, record the growth characteristics on each medium.
b) Examine the streak plates. Have single colonies been obtained? If so, describe the colonial morphology. If not, make a fresh subculture of the organism.

Gram films
Complete the preparation, examination and drawing of the Gram stain results.

Incomplete results
If you have failed to obtain results for any part of the experiment, consult a demonstrator. There may be time to set up a culture for next week.

Completion
Collect together all your results and, using the information supplied on the next page, identify each organism. Complete any outstanding work such as Gram results.

Report submission

1. Drawing of your own organism
2. Table detailing the following properties of each organism:
   a) colony morphology
   b) reaction to heat treatment
   c) growth on each of the media
   d) microscopic appearance and Gram reaction
   e) conclusion: which standard organism description fits each of the unknown cultures best (note any discrepancies or anomalous results).

Media and microorganisms supplied
Blood agar is an enriched medium which also has differential properties because of the ability of several organisms to cause haemolysis.
King, Ward & Raney's A medium is used to enhance the production of certain pigments, especially of *Pseudomonas aeruginosa*.

MacConkey agar is used for the selection of Gram -ve intestinal organisms. It has several ingredients with selective or differential functions, among them, bile salts which inhibit most non-intestinal bacteria; and lactose such that lactose fermenting bacteria grow as pink colonies whereas non-lactose fermenters are colourless.

Mannitol salt agar is a selective medium because it contains high salt concentrations.

Bacteria which may be provided include:

Bacillus cereus. A G+ve rod which is isolated from soil. It produces heat-resistant endospores which are difficult to stain.

Escherichia coli. A G-ve rod which inhabits the human intestine. It is able to ferment lactose.

Pseudomonas aeruginosa. A G-ve rod able to grow in many different habitats. It produces blue or green pigments under certain conditions.

Salmonella typhimurium A G-ve rod which inhabits mammalian intestines. It is unable to ferment lactose.

Staphylococcus aureus. A G+ve coccus which produces yellow colonies. It is found on human skin and hence is salt tolerant.

B4. Pharmacology

Practical 8: Effects of nitrous oxide – a double blind drug trial (Mike Hollingsworth, University of Manchester; mike.hollingsworth@manchester.ac.uk)

Intended learning outcomes
After the practical and appropriate study, students should have an awareness of:

- ethics of human experimentation
- measurement of analgesia
- analgesic and cognitive effects of nitrous oxide
- subject care needed for volunteers in clinical studies
- the design of a randomised placebo-controlled double blind drug trial
- experimental variation – factors to control and relevant statistical methods.

Pre-practical work

- In advance of the practical class students will review the ethical aspects related to human experimentation using reference materials provided, such as that provided by the Council for International Organizations of Medical Sciences (www.coms.ch/frame_guidelines_nov_2002.html).
- Students will understand the role and composition of an ethical committee which oversees human studies.
- Students will review a paper on methods of clinical trials to understand the differences between blind and non-blinded trials and the value of randomisation and a placebo-controlled trial.
- They will investigate the statistical power of pre- and post-treatment observations made in the same patient.

Protocol
This practical needs ethical approval and the presence of a medically qualified member of staff. Students must give informed consent. Students work in small groups of 2-4, one is the subject and the others act as observers responsible for the subject. The subject breathes room air via a mouthpiece connected to a Douglas bag. After 2 minutes equilibration, the following measurements are made:

- pain threshold (how long the subject can keep a hand in iced-water; limit 2 minutes)
- ability to substitute digits for symbols for 90 secs
- ability to copy digits from one page to another page for 90 secs
- completion of a checklist of feelings and sensations.

The subject then switches to breathing from a coded Douglas bag that contains either oxygen, oxygen with 20% nitrous oxide or oxygen with 40% nitrous oxide. After equilibration for 2 minutes the measurements are repeated. Class data is collected and statistically analysed.

Post-practical review
Students will:

- describe whether nitrous oxide had significant effects on pain threshold and cognition
- review the power of the statistical methods used and the reproducibility of this experiment vs. their other experience
- review potential improvements to the protocol
- discuss the issues involved in volunteering for clinical trials.

Practical 9: Potency ratio of two agonists (Ian Hughes, University of Leeds; i.e.hughes@leeds.ac.uk)

This experiment is a classical 1st year experiment and involves the production of data for the calculation of a potency ratio between two agonists on a guinea-pig isolated ileum preparation. The students carried out the work in two parts.

The first part was an assessed pre-laboratory exercise which counted toward module marks and for which students were required to complete and hand in a write-up by a set date. Only if this was completed were students allowed to do the laboratory class. The pre-laboratory work consisted of following a written schedule on a computer-based simulation of a guinea-pig isolated ileum to derive a simulated record from which measurements were taken to provide the data to calculate the potency ratio between two agonists. The schedule showed the students how to choose suitable doses to administer but did not specify what doses should be used. The simulation provided 'preparations' of different sensitivity. The schedule gave three options: dose-response curve to standard and a single dose of unknown; dose response curve to standard and to unknown; multiple dose response curves to both. Students were asked to justify their choice of method and describe the advantages and disadvantages of the 3 methods in the write-up. The students were required to write this up (brief introduction, data and graphical presentation, calculation, result) and the write up included some questions which had to be attempted (would the potency ratio be the same if determined on: a) another piece of ileum from a different guinea-pig? b) a piece of elephant ileum? c) a piece of skeletal muscle? In each case give your reasons.). This write up was peer marked and full feedback was provided.

The second part gave the students a choice. They could either sit a 20 min MCQ test or they could do a laboratory practical (50%, about 16, chose to do the practical). Both exercises provided marks which counted in the module assessment. The practical was marked on the quality of the data, the correctness of the calculation and the accuracy of the resulting potency ratio. Students could choose to work individually or as a pair and were marked as such. The apparatus was set up for them but the students prepared and set up their own tissue having been supplied with a 10cm piece of ileum. Students who wished to could watch the animal being killed and the length of ileum being removed. The class was staffed with demonstrators (3 final year students; paid), 2 postgraduate students, a technician and a member of academic staff. Training of postgraduate students was required but the final year students, who had in the previous year done lots of isolated tissue work, were asked only to revise their laboratory work on potency ratio. The students were provided with a known agonist (carbachol) and were given one A-Z unknown drug which they were told were new chemical compounds which they were testing. The unknowns were in fact one of four different strengths of carbachol (20, 8, 0.5 and 0.1 times stronger that the standard solution. Having set up their tissues, students were required to obtain constant submaximal responses and were told to then agree the method they chose to obtain the potency ratio with a member of laboratory staff. Most chose a single dose-response curve to carbachol and then a dose-response curve to the unknown. Some did multiple standard curves; some chose a single dose of unknown and assumed linearity and parallelism of curves. They had 4 hours to do this experiment, a one hour lecture slot being combined with a 3 hour practical. Students arriving late for whatever reason were not admitted. Students who were dissatisfied with the data they obtained were allowed back into the laboratory at a later date to repeat the practical work. The write-up from the practical was the trace of the experiment, a table of doses and corresponding responses, a log concentration – response curve graph and a potency ratio. This write-up was assessed by the member of academic staff on the basis of: how well the trace was annotated; had consistent submaximal responses been obtained; had two dose-response curves been obtained; were the data points reasonably located on the curves; was the potency ratio calculated correctly; was the potency ratio accurate as compared with the known value for the code letter they had been given.

This worked really well, there was a real buzz in the laboratory, and the students were enthusiastic, interested and worked hard. However, as student numbers increased from 30 to over 120 it became impossible to manage the numbers and the arrangement was discontinued.

This exercise in retrospect addressed many of the issues which the students raised as problems with first year practicals in the survey [1, 2].

Practical 10: Introduction to laboratory practicals (Michael Hayes Manchester Metropolitan University; M.Hayes@mmu.ac.uk)

The first year practical provision for Bioscience degree students within the SBCHS at MMU involves several parallel programmes with a number of subject specific differences in practical activities undertaken. It currently spans twenty seven teaching weeks with students being sub-divided into groups that undertake practicals according to a rota. Due to the complexity of the practical programmes and a requirement for all of our first year students to undertake a laboratory safety awareness test before they commence laboratory work an Introduction to Laboratory Practicals (ILP) activity has been introduced.

The primary aims of this activity are to enable first year students to understand how to work safely within the laboratories; how to calculate dilutions to achieve desired concentrations; how to draw a graph correctly; how to prepare a practical report and where to hand it in for assessment. Pre-laboratory preparation for our first year practical programmes involves a short presentation during Induction week a few days before the ILP activity. Students are told where to go, what they must bring to practicals (white laboratory coat and safety goggles) and where to put personal belongings before they enter the laboratories.

The ILP activity is a compulsory induction activity for all students undertaking first year laboratory-based practical work. It is a three hour activity that begins with staff introductions and an explanation of laboratory organisation. Students are then issued with a laboratory manual and are given explanations of its organisation and content. They are refereed to important appendices (Heath and safety in laboratories; Precautions for microbiology work; How to write-up practicals; Basic statistical calculations for practicals; Use of the light microscope) and the ILP activity schedule which has four parts that students, working in small groups, must complete before the end of the activity.

The first exercise enables students to understand how to work safely within University laboratories. This involves reading appendices and answering multiple choice questions (MCQs) that test their understanding of essential aspects of Heath and Safety in the laboratories. Following the practical the students must also complete the MCQ test on the University VLE system, which must be repeated until the pass mark is achieved. This also acts as an introduction to the VLE system and how to do on-line tests.

Since it is essential for Biological and Biomedical Scientists to know how to work out concentrations of solutions correctly and how to dilute solutions to achieve a desired concentration, the second part of the activity provides a theoretical exercise in calculating concentrations and making dilutions. In the third exercise students plot a standard curve on graph paper using data provided. They are then shown how to use the standard curve they have drawn to estimate the concentrations of some unknown samples. In the fourth exercise students read an appendix about writing up practicals which explains how to prepare a practical report and where to hand it in for assessment. They then answer questions about writing-up practical reports.

The introduction of this practical activity has improved the transition from practical work at school to that undertaken by our first year university students