GEES Subject Centre
Learning and Teaching Guide

Practical and Laboratory Work
in Earth and Environmental Sciences:
guide to good practice and helpful resources

Ian Williams

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1. School of Civil Engineering and the Environment, Lanchester Building, University of Southampton
2. School of Environment, University of Gloucestershire

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I Why Do Practical Work?

The purpose of this Guide is to discuss and promote the value of practicals and laboratory work, in the teaching of the Earth and Environmental Sciences (ES3) at undergraduate level. It suggests ways to improve the quality of learning that practicals can provide, outlines new ideas and suggests some texts and links that may be useful. In addition, it seeks to provide a framework in which teachers in Higher Education (HE) Earth and Environmental Sciences may analyse and evaluate current and future practicals so that learning outcomes become explicit.

1.1 Why provide students with practical work?

There are a number of key features which require us to rethink the ways we support students in the Earth and Environmental Sciences and to learn from the experiences of others. These include: increasing student numbers and diversity, cuts in the unit of resource, ‘value for money’ audits, modularisation and increasing pressures on academic staff time. Whilst practicals and laboratory work may be part of the taken-for-granted repertoire of ‘what we do in Earth and Environmental Sciences teaching’, it is important that from time to time we revisit those fundamental questions about what we are doing and why we are doing it.

Horobin et al. (1992, p.2) offered the following generic view of what comprises a practical class:

- Practical classes, irrespective of subject, depend upon:
  - A material, which may be anything from a document to a stone, from a set of mechanical or electrical components, to sets of solutions or people, maps, photographs or machines.
  - A script bearing a task or tasks. This might, for instance, be to construct or run equipment, to record in drawing and writing a report on specimens, to analyse text, to prepare a specimen of some kind, to perform practical activities and to record oneself doing it.
  - A protocol which explicitly describes a method or methods relevant to the task.
  - An appropriate environment facilitating the performing of the task. There may be a laboratory with handy benches, balances for weighing, computers, fume hoods, wide tables for maps, safety equipment. In fieldwork the environment provides the material for the class as well as its operational setting. For instance a chalk down, a high street, library, museum or a workplace of some kind.’

There are many elements in this broad view which would be familiar to Earth and Environmental Scientists, and it suggests a definition on the basis of what might be in a practical, but it does not include what goes on during the practical session — a topic we consider below. We might add to the above that a common characteristic of practicals is their student-centred nature. Students usually generate, collect and analyse data, come to conclusions and are involved actively in individual or group tasks. The extent of both academic and support staff involvement is variable, and the format may range from whole class teaching to independent learning. This process of ‘learning by doing’ is explored more fully below.

1.2 The aims of practical work in the Earth and Environmental Sciences

In the current literature on science education, a variety of views are expressed about the purpose of practical laboratory work, which might be extended to practical work in general. The objectives of (biochemical) practical work have been comprehensively summarised by Wood (1996), where, in addition to illustrating lecture material, objectives were categorised as developing ‘laboratory skills’ and ‘high level skills’. Wood (1996) states that laboratory skills involve learning how to follow protocols and work efficiently and safely, including manipulative skills, equipment operation, data recording, data processing and reporting skills. High levels skills include planning experiments, preparing protocols, critical analysis of data and of the literature, hypothesis forming, and communication of data and teamwork; we should perhaps also add problem solving to this list.

Some researchers (e.g. Wellington, 1989), have suggested that the ‘information explosion’ has resulted in a transition from a content-led to a predominantly process-led approach to practical teaching. The consequences of this change may be that:

- instruction in transferable skills has become more relevant than factual knowledge (Kotiw et al., 1999)
• there has been a loss in student interest in studying science at higher levels (Hodson, 1992)
• there is a lack of opportunity to practise the skills necessary for the conduct of many scientific professions (Johnstone and Letton, 1989)
• students progress to more advanced practical skills before they have mastered the ‘simpler’ skills, posing problems for lecturers in terms of demonstration and time management knowledge (Kotiw et al., 1999).

To overcome these problems, researchers such as Meester and Maskill (1995) and Kotiw et al. (1999) have devised courses that specifically seek to develop practical, cognitive and report writing skills concurrently.

Hofstein and Lunetta (1982, cited in Boud et al., 1986) emphasise the need to define the goals to which laboratory work could make a special and significant contribution, and to capitalise on the uniqueness of this form of teaching. So what is it that practicals, including laboratory work, can achieve that other forms of teaching and learning cannot? We might identify the following features:

• To bridge the gap between theory and practice and consolidate the theoretical understanding developed in a lecture course. In this case, the practical is closely integrated into a lecture course, and the practical is both demonstrating and reinforcing theory, as well as illustrating knowledge which might otherwise only be gathered from reading.

• Skills training, in particular to develop skills in handling apparatus. For example, how to produce a soil extract for testing, how to calibrate and use a meter for measurement of dissolved oxygen content, or how to identify pollen grains. A subsidiary, but important, aim here must be to develop professional attitudes to health and safety in the laboratory. The more generic skills of measurement, observation, reasoning, problem solving, working in teams, note-taking and presenting work in written and oral form are also important.

• To provide the experience of ‘doing science’, i.e. to develop practical, scientific, problem-solving skills. The practical might involve setting and testing hypotheses, or problem-solving; there might be an element of reflection on - or even questioning of - the scientific process, or on aspects of this such as sampling, or precision and accuracy. In particular, the Earth Sciences will inevitably expose students to the complexities of the ‘real’ world - the world beyond text book examples.

• To allow students to learn the method of and develop an attitude towards scientific inquiry – although it is argued by some that this may be also learned through classroom exercises in experimental design.

We might add the subsidiary social benefits of practical work, of bringing students closer to each other and breaking down barriers to communication and the exchange of views; this may lead to improved seminar and tutorial interaction. Practical work may also serve to break down barriers between students and staff.

It is important to remember, however, the limitations of practical laboratory work for ‘Practical class work is [normally] contrived to give valuable learning experience through very acutely directed small scale resources’ (Horobin et al., 1992).

Exley and Moore (1993) have noted that practical work in a typical science degree shows a change of skills emphasis with progression through the three years. The first year aims were more likely to involve skills training and practice, whereas projects that were tackled in the final year would emphasise problem solving or hypothesis testing.

Gibbs et al. (1997) proposed a checklist of questions to assist a tutor in a critical assessment of their practical:
• Is it worth doing at all?
• Is learning how to learn and to tackle unfamiliar situations more important than learning how to tackle identical situations?
• Is it necessary to do it or know how to do it, or is it sufficient to know about it, be familiar with it or appreciate it?
• Are students trained in the skills they are expected to demonstrate?
• Is students’ achievement of aims assessed?
• Do students see it or do it often enough to really achieve the aims?
• Can the aim be made explicit and tackled separately rather than remain implicit and buried amongst other aims?
• Is it dull, or can it be made more motivating?
• Which of these features that foster motivation are present?
  ◦ making something that works
  ◦ being oriented towards an end-product (such as finding a mineral deposit)
  ◦ real world contexts and problems
  ◦ association with modern hardware
  ◦ discovery
  ◦ open-ended problems
  ◦ unpredictability
  ◦ competition, especially between groups
  ◦ cooperation and social interaction
  ◦ novelty
  ◦ challenge, balanced with realistic goals and likelihood of success
  ◦ going beyond the technical content to environmental, social and human issues
  ◦ involvement of ‘outsiders’ – other years or courses, non-academics.

Use of this checklist might help to focus the practical, and the claims made for it, on those aims it can best achieve. It highlights the need to link assessment to learning objectives, and the importance of fostering motivation amongst the students. Use of the list, and of appropriate student evaluation, can also uncover gaps between intentions and outcomes.

It is important that the experiences offered by a practical are specifically identified as learning outcomes. In clarifying the particular aims that a practical will achieve, a necessary step is to formulate the learning objectives of the activity. Thus we might state ‘by the end of this practical the student will be able to…’ and state the intended learning outcomes.

Interestingly, one way in which the Earth and Environmental Sciences differ from other sciences is that practicals are rarely set up as demonstrations, with a known outcome. Instead, there tends to be a problem-centred approach with often more open-ended questions, which fosters greater motivation in the students, encourages acceptance of uncertainty and context-dependent outcomes, and serves to enhance transferable skills in graduates. Such an approach may allow the development of additional, unintended, student skills.
2 Learning Through Practical Work

2.1 The value of learning by doing

A common feature of practicals and laboratory work is undoubtedly the ‘hands on’ element offered to students – the ‘active learning’ or ‘experiential learning’ element. Active learning has been characterized by (Denicolo et al., 1992) as:

- a search for meaning and understanding
- greater student responsibility for learning
- a concern with skills as well as knowledge
- an approach to the curriculum which looks beyond graduation to wider career and social settings.

These approaches are highly valued by educationalists for the quality, transferability and depth of the learning experience they can provide. Lecturers in the Earth and Environmental Sciences need to look more closely at these terms (which some may dismiss as jargon), for the ideas behind them offer further reasons for conducting practical work. In particular, there is the efficiency argument, namely that the achievement of learning objectives involving understanding is considered to be more efficient where active learning is involved. One example of this is where concepts delivered in lectures are cross-referenced to particular practical experiences for the students, and results from the practicals are referred to in lectures. Here the practicals reinforce and develop further the initial conceptual teaching. Thus, activities which have traditionally taken place within practical classes in the Earth and Environmental Sciences degrees are in fact often in line with best educational practice, and are familiar to increasing numbers of students from their school experience. Further examples of active learning in the form of case studies can be found in Healey and Roberts (2005).

2.2 Learning by discovery

Discovery learning, or enquiry-based learning, is a particular form of active learning which can be highly motivating, and where the promise of discovery leads the student on. Nevertheless, it can be seen as an approach which lacks focus. Thus the challenge is to offer enough structure for the student to see the point of the exercise, whilst leaving enough freedom for a sense of discovery and individual challenge to remain. Discovery learning is not the same as experiential learning. Learning by doing is not simply a matter of letting learners loose and hoping that they discover things for themselves in a haphazard way through sudden bursts of inspiration. The nature of the activity needs to be carefully designed and the experience may need to be carefully reviewed and analysed afterwards for learning to take place (Gibbs, 1988).

Table 1 below provides a simple model for examining a proposed practical in terms of its enquiry content. The ‘Levels’ refer to the degree of openness of the enquiry, not to progress through a degree. Final year project work is usually at Level 3 in this model: students choose the problem to tackle. Practical classes tend to be around Level 2, with varying degrees of flexibility in the ‘ways and means’ available for students to choose. Some also require students to develop their own hypotheses to test, within a broader problem ‘envelope’.

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<th>Problem</th>
<th>Ways and means</th>
<th>Answers</th>
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<tr>
<td>Level 1</td>
<td>Given</td>
<td>Open</td>
</tr>
<tr>
<td>Level 2</td>
<td>Given, Open</td>
<td>Open</td>
</tr>
<tr>
<td>Level 3</td>
<td>Open, Open</td>
<td>Open</td>
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</table>

Many lecturers have discovered that, having developed successful active learning (whether specifically enquiry-based or not), there no longer appears to be a clear (or central) role for themselves. However there is a role, depending on the level of support you want to offer. Teaching in this situation means keeping a low profile, but being on hand to assist groups in overcoming obstacles, which also means you can observe whether the intended activities are effective. The facilitation in tasks might well be passed over to postgraduate demonstrators or support staff, but you would need to ensure that they understood the nature of the enquiry learning you are intending to promote. The innocent helpfulness of other staff can remove every element of discovery that had been carefully planned, as they provide the answers that student groups were seeking to discover.

2.3 Deep and surface approaches to learning

A deep approach to learning is essentially transforming, i.e.

- intending to understand material for oneself
- interacting rigorously and critically with content
- relating ideas to previous knowledge and experience
- using organising principles to integrate ideas
- relating evidence to conclusions
- examining the logic of the argument.

A surface approach to learning is essentially reproducing, i.e.

- intending simply to reproduce parts of the content
- accepting ideas and information passively
- not reflecting on purpose or strategies in learning
- memorising facts and procedures routinely
- failing to recognise guiding principles or patterns.

(Birnie and Mason O’Connor, 1998)

Building on the arguments for active learning, the provision of practicals as part of a course can be used to assist students in developing a deeper approach to their learning. The encouragement of responsibility for learning, of questioning assumptions and hypotheses, and of relating concepts to the interpretation of results, are all aspects of practicals demonstrated by the case studies in this Guide (see Sections 5 and 6), and by others (for example, Healey and Roberts, 2005). All these contribute to a deep approach to learning and move away from the idea that repetition of routine procedures is the essence of practical work (and the surface learning it would then promote).

So, the active or enquiry learning that currently takes place in our practical classes is thoroughly supported by research concerned with the effectiveness of teaching and learning. Its continued inclusion can be defended on the grounds outlined above. However, in order to improve on that experience, and to ensure that the activities we ask students to engage in really do deliver the experiences claimed for them, we need to consider the importance of reflection in learning.

2.4 The importance of reflection

Writers concerned with science education remind us that the learning process we imagine to be confined to the laboratory or practical classroom extends far beyond those walls. It also extends beyond the operation of a particular set of apparatus or item of computer software, and involves all the processes of student interaction and reflection which discovery promotes. Thus,

‘If we are concerned to promote active, student-centred learning, then it follows that students must be given the opportunity to “process” material for themselves ... If articulating thought and exploring ideas is an important part of learning, then verbal interaction - or dialogue - is a key part of the process’ (Coats, 1991).

Somewhere in our design of practicals we need to ensure that this opportunity for verbal interaction is promoted and structured effectively - at the very least, identifying when and how students will be enabled both to reflect on their experience and to incorporate the learning to inform future activity. This may extend to room layout, or timetabling matters:
'It is not sufficient simply to have an experience in order to learn. Without reflecting upon this experience it may quickly be forgotten or its learning potential lost. It is from the feelings and thoughts emerging from this reflection that generalizations or concepts can be generated. And it is from generalizations which enable new situations to be tackled effectively [...] It is not enough to do, and neither is it enough just to think. Nor is it enough simply to do and think.... Learning from experience must involve links between the doing and the thinking' (Gibbs, 1988).

2.5 Assessment of practical work in the Earth and Environmental Sciences

Assessment is the key means of ensuring that the stated learning objectives are explicitly addressed and of improving the quality of student learning. For example, laboratory practicals assessed by weekly reports might be appropriate where the only learning objective is defined as ‘training in specific laboratory techniques’. The quality of student skills might fairly be assessed by the data they have obtained. If the research skills of analysis and interpretation are also a stated learning outcome, assessment needs to include those particular aspects by demanding an element of reflection on the results and some evidence of comparison with published work. If transferable skills such as time-management or teamwork are involved, the form of assessment and the criteria involved might be very different: self assessment or peer review may be appropriate.

However, assessment of practical work is very time-consuming and too much lecturer time can be devoted to assessing students’ laboratory reports. Devices which might be used to alleviate this very real problem include:

• the assessment of selected specific practical exercises. It is important to stress, however, that this needs to be planned as part of the initial course design
• inspection of student lab records
• oral presentation and defence of selected lab records
• peer assessment of group exercises
• poster presentation of project work
• industrial supervisors contributing to the assessment process
• individual student profiles obtained from the cumulative assessment record
• development of a pro forma for an exercise or group of exercises which focuses on specific learning outcomes.
3 Transferable Skills Development in Practicals

Lecturers often make reference to the importance of skills development in relation to practical work. Whilst technical skills may be acknowledged in learning outcomes, it is also worth making explicit which generic transferable skills are being developed and assessed; these should be discussed with the students, not least so that they can confidently refer to these skills when they are preparing their curriculum vitae and making job applications. Thus, again, the transferable skills developed in a particular exercise or set of exercises should be identified in the learning outcomes.

Denicolo et al. (1992) provide a helpful list of transferable skills which may be useful to compare against those explicitly being developed in the students’ practicals and laboratory work.

**Problem-solving skills:**
- applying concepts and principles in analysing problems
- producing original or imaginative products or ideas
- using numerical or statistical analysis to solve problems

**Initiative and efficiency:**
- using initiative, and carrying out one’s own ideas
- achieving results within realistic financial and time constraints
- showing greater self confidence
- taking responsibility for one’s own development

**Interactional skills:**
- working co-operatively with others in a group or team
- interpreting and understanding feeling and behaviour
- leading and organising group activity

**Communication skills:**
- making effective oral presentations in formal situations
- producing effective, well-designed written presentations
- demonstrating computer literacy
- making oneself understood in a foreign language.

The Quality Assurance Agency for Higher Education (QAA) in the UK published a subject benchmark document for Earth Sciences, Environmental Sciences and Environmental Studies (ES3) (QAA, 2000). This document lists the Graduate Key Skills that should be developed in ES3 degree programmes under six headings:

- Intellectual skills
- Practical skills
- Communication skills
- Numeracy and Communications and Information Technology (C and IT) skills
- Interpersonal/Teamwork skills.
- Self management and professional development skills

The key practical skills were identified in a very non-specific fashion as:

- Planning, conducting, and reporting on investigations, including the use of secondary data
- Collecting, recording and analysing data using appropriate techniques in the field and laboratory
- Undertaking field and laboratory investigations in a responsible and safe manner, paying due attention to risk assessment, rights of access, relevant health and safety regulations, and sensitivity to the impact of investigations on the environment and stakeholders
- Referencing work in an appropriate manner.

The QAA’s list prompts a word of caution. With the current emphasis on generic, transferable skills, it is important not to lose sight of the particular Earth and Environmental Science skills that are also being developed in a specific
practical. If our practical exercises claim all transferable skills for themselves, at the expense of the technical skills we are also seeking to teach, then the purposes of our teaching sessions become doubtful. Each session will begin to appear the same and the assessment criteria will look identical.
4 The Nuts and Bolts of Practical Work

4.1 Introduction

Laboratories for Earth and Environmental Science frequently contain chemicals and equipment that can potentially cause significant harm to laboratory workers and damage to the laboratory. In addition, samples from field or project work sometimes contain substances and/or organisms that may constitute a chemical or microbiological hazard, for example river water or sewage effluent. The hazards and risks from these sources are familiar to academic staff and normally identified and addressed via a Hazard Identification and Risk Assessment (HIRA) form, and the Control of Substances Hazardous to Health (COSHH) procedures (see Section 4.7). However, in today’s increasingly litigious society, it is even more important to emphasise to students that laboratory work requires a high level of health and safety awareness, a full understanding of, and compliance with, laboratory safety procedures, and appropriate safety equipment and clothing.

This section provides general advice on specific aspects of laboratory work, for example, laboratory equipment, health and safety, support staff and laboratory techniques. Although much of this will be familiar to established academic staff, we hope the text provides useful checklists and resource guides as well as reference material.

4.2 Laboratory planning

The physical space for practicals is essential. Room designs express the assumptions of designers about how learning will occur. Once established, rooms can shape the activities that take place within them. It is noteworthy then that the planning and arrangement of laboratory furniture has an effect on the nature of the teaching and learning. Laboratory planning for the Earth and Environmental Sciences should be based on the learning objectives of the practical curriculum and the skills which are to be taught.

Specialist research laboratories are are normally considered out of bounds during undergraduate education, although visits to, and demonstrations, of such equipment may be important in certain courses.

4.3 Laboratory types and equipment

Undergraduate laboratories for Earth and Environmental Science vary widely in the layout of laboratory furniture and equipment. This is understandable given the variety of activities undertaken, but it is essential that workbenches allow sufficient space for an individual to work safely and to allow ease of access in case of an accident or emergency (see Table 2 and Sections 4.7 and 4.14).

Laboratory equipment includes general equipment such as glassware, spatulas, thermometers, balances, ice and heated water baths, heating mantles, weighing boats, basins and ultrasonic baths, as well as more specialized equipment for analytical determinations. Specific texts that contain diagrams of typical laboratory equipment, some with brief explanations of their purpose(s), have been marked with a superscript A (A) in the reference section (Section 9).

In addition, many laboratories will contain side benches along the walls and furniture such as stools, fume cupboards, incubators, drying cabinets, ovens and refrigerators. A separate room or preparation area for technical staff is often adjacent to the laboratory.

Work benches used for practical work involving chemicals are typically coated with a water-impermeable surface which will resist chemical attack from acids, bases and organic chemicals. Utilities available at each workspace may include electrical plug points, water, sinks, gas taps (for Bunsen burners), gas taps for drying glassware (compressed air) and use in preparative chemistry (e.g. nitrogen, argon), and a temporary storage area for chemicals in use (often a raised shelf). Underneath the benches, there are sometimes cupboards and drawers for storing equipment, tools and glassware. It is important that all these features are pointed out to students and that appropriate signage is in place.

However, laboratories for Earth and Environmental Science may also have a number of specialist features. These features may be divided into two categories: equipment that is used regularly, and safety equipment. We suggest that students should be encouraged to make a mental note of their location when they first use the laboratory and should be reminded, and perhaps even tested, periodically. This may seem trivial, or even condescending, but we would suggest that it is good practice and helps to raise students’ awareness of health and safety issues.
Laboratory equipment that is used regularly includes:
- distilled and double-distilled, de-ionised water, available in plastic dispensing bottles which require refilling from a central still or large plastic container
- balances for weighing samples, chemicals etc.
- paper towels for clearing spills
- sinks for washing hands, and adjacent hand-dryers
- separate bins for disposing of broken glass and paper/plastic waste (students should be told never to cross-contaminate these bins – it can be dangerous for staff when they remove the waste)
- specialist locations or containers for the disposal of chemical waste such as acids, organic chemicals and wastewater samples (again, students should be reminded never to cross-contaminate chemicals – if the containers are full, they should be told to ask advice from a tutor or technician)
- hooks or areas for the storage of clothing (laboratory coats, jackets) and bags.

Safety equipment commonly available in laboratories used for the Earth and Environmental Sciences is discussed in Section 4.7.

4.4 Support staff for practical classes
The successful delivery of practical classes often depends upon postgraduate demonstrators and technical support staff. These may be the principal point of contact for undergraduates carrying out practical work. The undergraduate teaching and learning experience will be mediated by this. Good practice involves a favourable staff-student ratio, and staff development which involves all contributors to the student experience. In particular it is important that postgraduates and technicians are given adequate support and training prior to running a practical class (see for example Goodall and Elvidge, 2003). This may take the form of an organized course, or an informal briefing well in advance of the class. This is even more important in the case of technical support staff, in whose domain the work is often being conducted. Responsibilities here include:
- confirmation of the time and place of each class
- confirmation of student numbers involved, possibly with a list of their names
- copies of the protocols a class will use
- a briefing on the practical and details of any changes from the last time the class was run
- a copy of any workbook.

4.5 A note about the responsibilities and work of laboratory technicians
The role of technical staff in the laboratory is to maintain, set up and clear away equipment, prepare solutions of chemicals, obtain environmental samples for testing and maintain adequate stock control. Technical staff also have responsibilities for health and safety and good laboratory practice. Some technicians can demonstrate equipment and/or procedures to students and provide technical and safety advice. Technicians often have other roles outside the laboratory.

However, laboratory technicians are not employed to do students’ tasks for them nor are they expected to clear up unreasonably messy workbenches. Instructions given by technicians about safety or working practices must be obeyed. Students needing help must not expect technical staff to drop their current task(s) immediately as they often work to tight deadlines. Consequently, students should be told clearly that, if they require advice or assistance from a technician, it is best to make an advance appointment.

4.6 Student induction to laboratory and practical work
Widening access, student diversity – in particular the increase of students from ‘non-traditional’ backgrounds – and modularisation of degree courses present the Earth and Environmental Sciences lecturer with a group of students with a wide range of previous experience. This can pose a challenge in terms of the effective use of laboratories for
teaching and learning. In view of the diversity of student background, particularly on modular Earth and Environmental Science degree courses, it would seem advisable to incorporate an element of student induction to laboratory work, including health and safety issues. Such an induction involves a familiarisation process, whether of laboratory apparatus or computer keyboards, in a supportive environment in order to alleviate student apprehension. Those considered to have appropriate backgrounds could be exempted on the basis of evidence of their knowledge and skills. One approach to student induction to laboratory and practical work is outlined in Appendix 1.

Gibbs et al. (1997, p.21-22) suggest that a library of instructional videos for various experimental instruments and rigs is made available to all students. They are asked to become familiar with these instruments on an ‘open lab’ basis – i.e. laboratories, equipment and technical support are timetabled in a regular slot and students organize their learning themselves using the support materials available (only really possible with more advanced students). Students are then tested by multiple choice questions or brief observation by a technician.

Another example from the same source is a variation on the ‘circus’ (see Gibbs et al., 1997) with peer tutoring of equipment use. In the first week each student group is given a piece of equipment with which to become familiar (and possibly some exercises or experiments which will help this process of familiarization). Each group becomes the ‘expert’ on their piece of equipment for future weeks, briefing the next group who need to use it and helping them to overcome any problems they encounter. Groups rotate around equipment.

4.7 Health and safety issues

Health and safety should inform and underpin all good practice in practical and laboratory work. Institutions and departments should have clear, readily accessible and known guidance policies and procedures for health and safety. A strategic approach is to introduce and involve issues of safety in all aspects of your courses. Deciding to do this will probably influence the way you prepare course documentation, as well as the way you run and assess the practical activities themselves.

We should not forget that the potential for accidents in a laboratory is considerable. The accidents can be relatively minor (cuts from broken or damaged glass) or extremely serious (a major explosion, fire or release of toxic fumes). Although major accidents in university laboratories are very rare, because of the presence of trained staff and specialised safety equipment, this is not reason for complacency. The major potential hazards associated with laboratory work are:

- **Fire**
- **Chemicals** that may be taken into the body by ingestion, inhalation, or through skin contact
- **Radiation** from a variety of sources, including radioisotopes, ultra-violet light, lasers and microwaves
- **Electrical or physical**, including autoclaves, vacuum and pressure vessels, gas cylinders, freezers, liquid nitrogen containers, and all electrical equipment in the laboratory
- **Sharp objects** – needles and broken disposable glass pipettes are one of the most common causes of minor injuries
- **Infection with certain micro-organisms** – for example, viruses, parasites or bacteria that are themselves under study in the laboratory, or that may be present as contaminants in samples under analysis.

Most universities and industrial companies have their own Health and Safety Policy that must conform with the legal requirements set out by legislation; for example in the UK, health and safety policies are governed by The Health and
Safety at Work etc. Act 1974. The Policy will outline the responsibilities of all staff and students who use laboratory facilities. The Control of Substances Hazardous to Health (COSHH) is governed by the COSHH regulations (1988), and other regulations. A list of useful publications is provided in Box 1.

Box 1. Useful health and safety information

The Health and Safety Executive (http://www.hse.gov.uk/)
HSE Information Centre, Broad Lane, Sheffield, S3 7HQ

Publications include:
- General COSHH (Control of Substances Hazardous to Health) Approved Codes of Practice (ACoP) Carcinogens ACoP (Control of carcinogenic substances) and Biological agents ACoP (Control of biological agents). Control of Substances Hazardous to Health Regulations 1994. Approved Codes of Practice 1995. ISBN 0 7176 0819 0.
- Introducing COSHH – Leaflet IND(G)65(L)
- Introducing Assessment – Leaflet IND(G)64(L)
- Hazard and Risk Explained – Leaflet IND(G)67(L)

The Royal Society of Chemistry (http://www.rsc.org/)
Burlington House, Piccadilly, London, W1V 0BN

Resources include:
- COSHH in Laboratories, Environment Health and Safety Committee Note
- Health, Safety and Toxicology, Current Awareness Databases including Laboratory Hazards (monthly bulletin)
- Chemistry Education Research and Practice (journal)

Her Majesty's Stationery Office (HMSO) (http://www.hmso.gov.uk/)
PO Box 276, London, SW8 5DT

Publications include:

Institute of Occupational Medicine (http://www.iom-world.org/)
Roxburgh Place, Edinburgh, EH8 9SU

Resources include online research reports and scientific papers

In general, the overall responsibility for ensuring safety in any laboratory rests with those who have managerial responsibility in that laboratory. Although one person is often designated as ‘laboratory manager’, on a day-to-day basis, technical staff are responsible for the provision of safe equipment, storage and maintenance, and teaching staff for the overall safety of the students and their activities. The students must take responsibility for their own actions and take every reasonable precaution to ensure their own safety and that of others. It is imperative that students obey the laboratory health and safety rules and any instructions given to them by tutors and technicians.

All chemical substances used in laboratories must be stored in safe conditions, and only the minimum amounts brought into the working area. Small quantities of less hazardous chemicals can be stored on racks and shelves in the laboratory. A great deal of thought must be given to the location of storage space, their layout and their
contents. Hazards can easily arise as a result of the intermixing and reaction of chemical substances due to breakages, spillage or fire. Photocopiable lists of guidance for the safe storage of chemicals and general safety rules for students are available in Appendices 2 and 4; these are not complete lists, merely an indication of typical safety rules. Local safety rules may differ slightly in each laboratory depending upon circumstances, although they must always conform with legal requirements and good laboratory practice; safety rules are only useful if they are followed and enforced.

Safety equipment commonly available in laboratories used for the Earth and Environmental Sciences is usually sign-posted and includes:

- a shower, for use if clothing catches fire or in the event of a large spill of caustic chemicals on an individual
- facilities for flushing chemicals out of an individual’s eye with cold water or saline solution
- fire buckets, blankets and extinguishers (it is particularly important that staff and students know the different types of fire extinguisher and their application)
- spill kits, to prevent the spread of spilled chemicals that may be hazardous
- a health and safety noticeboard that displays information such as chemical data sheets, location of fire exits, first aid procedures and contact points for staff qualified in first-aid
- safety spectacles or goggles, full face-shields, disposable gloves and heat-resistant gauntlets, for use as appropriate
- a dustpan, brush and mop, for clearing broken glassware and water spills respectively
- a telephone, so that the emergency services – fire/ambulance/police – can be called if necessary.

It is worth re-emphasising that all students, technical and academic staff should wear eye protection when performing experiments in a laboratory. Depending upon the nature of the planned experiment, safety glasses, goggles or full face shields may be necessary. Prescription spectacles may provide sufficient protection, but only if they have been designed so that they prevent splashes entering the eyes from the top, bottom and sides. Contact lenses provide no adequate protection.

It is good practice for laboratory users to familiarise themselves with hazard warning symbols (see Appendix 5). These symbols are normally shown black on an orange-yellow background. Similarly, it is good practice for students to be guided to locate and remember the position of the fire exits, showers and other safety features in the laboratory; this could form part of students’ induction to laboratory work (see Section 4.6).

4.8 The reporting of accidents

All accidents, however minor, must be reported and recorded in a designated document. Accidents include spills of chemicals or water and breakage of equipment, as well as personal injury. A formal, written record is usually kept for accidents that result in personal injury or property damage, and occasionally a written report is needed for more serious incidents. A photocopiable example of an accident report form is available in Appendix 6. Such records are needed for COSHH, the Health and Safety Executive and for insurance purposes, as well as to alert staff to any unsafe practices or working conditions.

4.9 Emergency procedures

There are a number of basic actions that should be taken in order to minimize the risk of injury or property damage in the event of a laboratory emergency. In the event of a laboratory fire, explosion, release of toxic substances or similar imminent danger, the following actions should be taken:

- evacuate the laboratory through a designated exit
- sound the fire alarm so that all persons evacuate the building, if appropriate
- do not re-enter the laboratory or building (as applicable) until advised that it is safe to do so by a Health and Safety Officer.

An example of a notice outlining an evacuation procedure in the event of a fire is shown overleaf. Students should be advised to report any emergency situation immediately to an appropriate member of staff.
FIRE

EVACUATION PROCEDURE

When the alarm sounds:

• Leave the building immediately by nearest exit and follow the green and white signs and the instructions of site operations staff.
• Do not stop to collect belongings.
• Do not use lifts.
• Close doors and windows behind you.
• Assist people with special needs – ask how you can help.
• Staff must report any problems and cleared rooms to Evacuation Controllers.
• Stand clear of the building / go to the assembly point.
• Do not re-enter the building until instructed by site operations staff.

FIND OUT where the fire notices are and read them.
FIND OUT where the nearest fire exits and alternative stairways are.
FIND OUT where the fire equipment / call points are.
REMEMBER keep fire exits clear at all times.

BE AWARE – BE SAFE
4.10 Storing and handling chemicals and biological materials

All students should be made aware of the general principles of storing and handling chemicals and biological materials. Photocopiable guides are presented in Appendices 2 and 3.

4.11 Use of fume cupboards

A fume cupboard is a special piece of laboratory furniture that safely removes potentially hazardous fumes that may be generated during the use of chemicals. The main safety features include an extraction system to remove (and sometimes treat) waste gases, an explosion-proof sash window that moves up and down to allow access and external controls for gas, water, electrical and vacuum services. The extraction fan must always be switched on when the fume cupboard is in use and apparatus in the cupboard must not interfere with the efficient opening/closing of the sash window. The release of toxic or hazardous fumes should be minimized, if necessary, by the use of scrubbers or similar devices fitted to the exhausts of the apparatus used. Any reaction that results in a serious discharge of gas must be notified to the laboratory supervisor immediately.

The safety features built into fume cupboards can lead to complacency when they are being used for experiments. However, normal protective clothing, including eye protection, must be worn when using fume cupboards.

4.12 Project work and working alone

Students should be reminded of the following issues when carrying out project work / working alone in the laboratory:

- projects involving practical work require careful planning and consultation with others; in particular COSHH and HIRA forms should be completed for all activities (see Appendices 7 and 8)
- project work may only be undertaken under the supervision of a tutor or qualified technician/researcher
- laboratory and instrument technicians must be made aware of the nature of the project and be given adequate warning of the required equipment/chemicals; equipment may not always be available immediately
- students should receive proper training in the use of new equipment and an assessment of their proficiency should be made before they are allowed to work independently
- procedures for loaning equipment to students should be carefully managed and any faults or accidents that occur during its operation should be reported.

4.13 Laboratory notebooks

In our experience, undergraduate students need to be constantly reminded to keep accurate and detailed notes of their laboratory experiments whilst the work is being done. Texts that provide guidance on organising and keeping laboratory notebooks have been marked with a superscript B (§) in the reference section (Section 9).

4.14 Disabled students

Disabled students include those with:

- blind / vision impairments
- deaf / hard of hearing
- physical/mobility impairments
- hidden disabilities (including dyslexia)
- mental health difficulties.

The Disability Discrimination Act (DDA) Part 4 (Education) applies to all areas of education, including Higher Education. It makes it unlawful to discriminate against disabled people or students by treating them less favourably than other students. The requirements of the Special Educational Needs and Disability Act 2001 (SENDA) cover
admissions and enrolments to courses, exclusions, and the provision of other student services, where ‘student services’ includes services of any description provided wholly or mainly for students or those enrolled on courses (i.e. learning and teaching activities).

Practical classes and laboratories can create barriers for some disabled students. Catering for disabled students in laboratories may require adaptations that are relatively easy to make and benefit all students, e.g. modifications to signage; improved access to workbenches; and strategic placement of lamps to improve visibility of equipment or computer screens. More elaborate adaptations may be required for students with mobility and/or vision impairments. Some ideas to assist lecturers and demonstrators to meet the needs of disabled students, and some modifications that disabled students may require, are listed below (adapted from guidance by Oxford University Disability Office, 2003).

• Consider meeting a disabled student prior to classes starting, to show them around the laboratory, giving details of the type of equipment to be used and the tasks to be performed. This will assist the student to determine the support they will need during these practical classes.

• Identify the core elements of the laboratory work to be undertaken. This will help you and the student to decide what adaptations may be necessary.

• Consider talking to the student about items of adaptive technology that may assist them in practical classes. Laboratory technicians may also have some helpful suggestions.

• A disabled student may have a laboratory assistant who can (under instruction from the student) perform certain tasks that the student is unable to execute. The laboratory assistant is there to facilitate student learning.

• For students who are unable to perform certain laboratory activities, there may be alternative forms of learning that they can access, e.g. computer simulations.

• Consider giving laboratory protocols and experiment details to students in advance. This may enable students to pre-empt any difficulties; it also allows students with dyslexia to familiarise themselves with the material in advance and reduces the pressure on them to read and understand information quickly in the laboratory.

• It is good practice to give instructions in both a written and verbal format; this allows all students to refer back to the instructions while they are working, but also helps to ensure that those with a print disability have access to them. A print disability is a disability that makes it difficult for someone to read or access standard print. This usually refers to students with vision impairments and those with dyslexia.

• In case of an emergency, have an evacuation plan in place that meets the needs of disabled students. It may be necessary to locate a ‘safe area’ in which a student can wait until they can be evacuated.

The TechDis Accessibility Database contains over 2,500 items of assistive technology used to support students with disability (http://www.techdis.ac.uk/access.html). Further general advice and strategies for approaching laboratory work for disabled students is given in Perie et al. (2003) and in Section 7. In addition, the Quality Assurance Agency for Higher Education in the UK provides a Code of Practice for students with disabilities (QAA, 1999).

### 4.15 Laboratory techniques

Ideally, in order to support their practical activities, students should be given opportunities for prior or simultaneous learning on:

• observation and recording

• detection limits and sensitivity

• errors, precision and accuracy

• data analysis, interpretation and evaluation

Texts that provide useful guidance and student exercises on these topics include Dean et al. (2002), Harris (2001), Jones et al. (1999), Radojević and Bashkin (1999) and Williams (2001).

### 4.16 Physico-chemical techniques

Students of the Earth and Environmental Sciences routinely handle and analyse samples from different environmental domains (water, soil, sediments, rocks and fossils, air, vegetation, etc.) and hence require training in a range of basic
laboratory (and fieldwork) skills and techniques. These may include:

- using and assembling general laboratory equipment, including support stands, clamps and clamp holders, glassware (e.g., distillation and reflux equipment), etc.
- using laboratory services and equipment such as gas tanks, fume hoods and cupboards, electrical equipment, water dispensers, microscopes, etc.
- measuring and dispensing liquids, using manual and auto pipettes, flasks and beakers, measuring cylinders, burettes and syringes
- holding and storing liquids, using test tubes, beakers, flasks, bottles and vials
- cleaning, handling and disposing safely of glass, plastic, ceramic and metal equipment
- preparing solutions and dilutions
- performing filtrations, using gravity and suction filtration techniques and a range of different filter papers
- heating and evaporating solutions, chemicals, liquid and solid samples, etc., using gas burners, steam, water and oil baths, hot plates and stirrer hot plates, electric heating mantles, sand baths and hot-air guns
- drying glassware, liquid and solid samples, vegetation, etc., using desiccators and ovens
- cooling solutions, chemicals, liquid and solid samples, etc., using ice baths, solid carbon dioxide and liquid nitrogen
- sieving soils and sediments using manual and automatic techniques
- maintaining and calibrating equipment
- volumetric analysis
- gravimetric analysis.

Two useful texts that provide practical guidance for lecturers and students alike are those by Boud et al. (1986) and Coyne (1997). Although a little dated now, Boud et al. (1986) provides a comprehensive guide to the design and organisation of laboratory activities and the conduct of laboratory teaching. Coyne (1997) provides a practical guide to materials, equipment and techniques and offers complete coverage of all commonly-used laboratory equipment.

4.17 Literature sources: practical advice and exercises

Literature sources that contain examples of practical advice and exercises relating to basic laboratory skills and procedures that may be required by Earth and Environmental Science undergraduates are listed alphabetically below. In many cases, the author(s) provide step-by-step guidance on how to carry out a particular procedure; for example, the textbook by Dean et al. (2002) has useful boxes on weighing out solids, making up solutions of known concentrations and performing dilutions from standard solutions. Such boxes can be combined to support (or create) laboratory practical classes that develop these key practical skills. Thus, the boxes provided by Dean et al. (2002) may be combined to enable a student to determine the sodium concentration of rain- or sea-water using a flame photometer whilst developing key laboratory skills (quantitatively weigh out a known amount of sodium chloride; make up an aqueous solution of a known concentration of sodium; and make up a linear dilution series of calibration standards from a standard solution).
Using and assembling general laboratory equipment and services
Dean et al. (2002); Harris (2001); Williams (2001)

Measuring and dispensing liquids
Dean et al. (2002); Harris (2001); Jones et al. (1999)

Holding and storing liquids
Dean et al. (2002); Harris (2001); Jones et al. (1999)

Cleaning, handling and disposing safely of, glass, plastic, ceramic and metal equipment
Dean et al. (2002); Harris (2001)

Preparing solutions and dilutions
Dean et al. (2002); Harris (2001); Williams (2001)

Using weighing containers; general purpose, spring and analytical balances
Dean et al. (2002); Harris (2001); Williams (2001)

Performing filtrations
Dean et al. (2002); Harris (2001)

Heating and evaporating solutions, liquid and solid samples etc.
Dean et al. (2002); Harris (2001)

Drying glassware, liquid and solid samples etc.
Dean et al. (2002); Harris (2001)

Cooling solutions, liquid and solid samples etc.
Dean et al. (2002)

Sieving soils and sediments
Rowell (1994)

Maintaining and calibrating equipment.
Dean et al. (2002); Harris (2001); Williams (2001)

Volumetric analysis
Dean et al. (2002); Harris (2001); Williams (2001)

Gravimetric analysis
Dean et al. (2002); Harris (2001); Williams (2001)

Using microscopes
Jones et al. (1999)

Identifying organisms and using identification keys
Jones et al. (1999)

Photography and imaging
Jones et al. (1999)

Growing and enumeration of micro-organisms
Gross et al. (1995); O’Leary (1989); Rump and Krist (1988)

Sterilisation, disinfection, and antisepsis
O’Leary (1989); Rump and Krist (1988)

Stains for light microscopy
O’Leary (1989)

Preservation of micro-organisms
O’Leary (1989)

Enrichment culture for micro-organisms
O’Leary (1989); Rump and Krist (1988)
4.18 Instrumental techniques in Environmental Sciences

Earth and Environmental Science students will often be required to analyse environmental samples for information. Some brief guidance for students on the sorts of information obtainable from environmental analysis is provided in the box below.

In qualitative analysis, we try and determine what substances are present in our unknown sample. In quantitative analysis, we try and determine how much of a particular species (the analyte) is present in our unknown sample. Quantitative analysis provides numerical information, often in the form of a concentration term, about the analyte.

Methods used for quantitative analysis of environmental samples may be categorized as classical or instrumental methods, although this distinction is largely historical and artificial. Classical methods of analysis include traditional techniques such as gravimetry, titrimetry and volumetry. Instrumental methods all depend upon the use of a suitable instrument to determine some physico-chemical parameter of an analyte, such as an electrical or an optical property. Instrumental methods are generally faster than classical methods, and are perfectly suited to the performance of a large number of routine determinations. All analytical methods involve the correlation of a physical measurement with the analyte concentration.
5 Examples of Laboratory Practical Exercises in Earth Sciences

Some examples of practical exercises for use with Earth Science undergraduates which have been documented in the recent literature are listed below.

5.1 Data sources
- Web resources review – Maps and Map tools (Francek, 2002)

5.2 Economic geology
5.2.1 Metalliferous mineralisation
- Gravity methods in mineral exploration (Dentith and Wheatley, 1999)
- A mineral exploration campaign (Beaudoin, 1999)
- 3-D mine mapping (O’Connell, 1995)
- A mineral resource and mining feasibility project (Mumin, 2000)

5.2.2 Oil and gas
- Downhole logging using resistivity (Tempel, 1998)
- Burial history of the North sea and hydrocarbon maturation (Swarbrick, 2000)

5.3 Engineering geology
- A road construction exercise (Baskerville, 1997)
- Environmental geophysics using magnetic and gravity methods in a contaminated land investigation (Thomas, 2000)

5.4 Environmental geology
- Environmental geophysics using magnetic and gravity methods in a contaminated land investigation (Thomas, 2000)
- GIS exercise to study environmental risk (Stewart et al., 2001)

5.5 Geochemistry
- Sample contamination (Anderson, 2001)
- Modelling non-equilibrium chemical reactions (Levy and Mayer, 1999)
- Aqueous species calculations (Roberts, 2000)
- Stable isotope geochemistry (Kirscher et al., 2000)

5.6 Geo-hazards
- Impact cratering (Basu &and Eigenbrode, 1998)
- A decision-assessment matrix in volcanic hazard management (Hodder, 1999)
- Forecasting a volcanic eruption (Mattox, 1999)
- Predicting a volcanic eruption (Gravestock, 1999)
- Understanding of risk (Lutz, 2001)
- Magma ascent rates at Mount St Helens (Farver and Brabander, 2001)
5.7 Geological maps and GIS

- Implementation of GIS into introductory Geoscience (Hall-Wallace and McAuliffe, 2001)
- 3-D mine mapping (O’Connell, 1995)
- British geological maps suitable for undergraduate use (Clayton, 1996)
- GIS exercise to study environmental risk (Stewart et al., 2001)

5.8 Geophysics

- Downhole logging using resistivity (Tempel, 1998)
- Gravity methods in mineral exploration (Dentith and Wheatley, 1999)
- Environmental geophysics using magnetic and gravity methods in a contaminated land investigation (Thomas, 2000)

5.9 Hydrogeology

- Ground water pollution (Rich and Onasch, 1997)
- Groundwater investigation (Lee, 1998)
- Darcy’s law taught through experimentation (Nichol and Scott, 2000)

5.10 Igneous petrology

- A decision-assessment matrix in volcanic hazard management (Hodder, 1999)
- Forecasting a volcanic eruption (Mattox, 1999)
- Magma ascent rates from mineral reactions (Farver and Brabander, 2001)
- Phase equilibria modelled by synthetic fluid inclusions (Darling, 2000)

5.11 Introductory geology

- Introductory practical exercises in geology (Owen, 2000)

5.12 Metamorphic petrology

- Thermal conductivity and contact metamorphism (Moseley, 1998)

5.13 Mineralogy

- Mineral thermodynamics (Stracher et al., 1998)
- Mineral identification (Hudson, 1995)
- Making an accurate three dimensional model of any crystal from its stereogram (Erickson and Barthelmy, 2000)
- X-Ray diffraction simulation (Johnson, 2001)

5.14 Palaeontology

- Experimental fossil preservation (Mankiewicz, 1998a)
- The processes of fossilization (Babcock, 1998)
- Preservation potential of fossils (Soja, 1999)
- Fossil borings and bio-erosion (Mankiewicz, 1998b)
- Palaeobase – a visual database of fossils from Blackwell Scientific and the Natural History Museum, reviewed by Young (2001)
5.15 **Planetary geology**
- Cratering (Basu and Eigenbrode, 1998)

5.16 **Sedimentology**
- Basin analysis (Soreghan and Soreghan, 1999)
- Burial history of the North sea and hydrocarbon maturation (Swarbrick, 2000)

5.17 **Stratigraphy**
- Geological time (Spencer-Cervato and Daly, 2000)

5.18 **Structural geology**
- Fault reactivation (Alaniz-Alvarez et al., 2000)

5.19 **Tectonics**
- Plate motions from linear regression (Hall-Wallace, 2000)
6 Examples of Laboratory Practical Exercises in Environmental Sciences

Literature that includes details of laboratory experiments and instrumental techniques relevant to Environmental Sciences is listed below. Some of the literature listed refers the reader to internationally-recognised methods for the analytical determination of substances in the environment. These texts are key references that may be used by more advanced students for project work, or may be modified by lecturers to suit the level of a laboratory class and the time/resources available. Other texts e.g. Radojević and Bashkin (1999) and Williams (2001) provide step-by-step guidance to the reader on performing a named environmental determination.

6.1 General literature
- Barceló (2000); Barceló (1993); Baum (1998); Buffle and van Leeuwm (1992); Dean (1998); Fifield and Haines (1995); Jones et al. (2000); Kebbekus and Mitra (1998); Manahan (2000); Reeve (2002); Skoog et al. (1990)

6.2 Analysis of natural waters
6.2.1 General literature
- Greenberg et al. (1992)

6.2.2 General water quality parameters
- Harris (2001) – pH
- Radojević and Bashkin (1999) – total solids, total dissolved solids, suspended solids, fixed and volatile solids, settleable solids, pH, conductivity, redox potential, hardness, alkalinity
- Vowles and Connell (1980) – pH, conductivity, suspended solids
- Williams (2001) – hardness

6.2.3 Oxygen demand
- Ondrous (1993) – BOD\textsuperscript{1}, DO\textsuperscript{2}
- Radojević and Bashkin (1999) – BOD, COD\textsuperscript{3}, DO
- Vowles and Connell (1980) – BOD, DO
- Williams (2001) – BOD, COD, DO

1. Biological Oxygen Demand. 2. Dissolved Oxygen. 3. Chemical Oxygen Demand

6.2.4 Inorganics
- Demay et al. (1999) – anion content
- Harris (2001) – ammonia, anion content, bicarbonate, calcium, carbonate, chloride, magnesium, nitrite, phosphorus
- Hughes (1993) – ammonia
- Ondrous (1993) – nitrate, phosphate in water and detergents, salts
- Radojević and Bashkin (1999) – ammonia, chloride, fluoride, heavy metals (Al, Cu, Pb, Hg, Sn), iron, nitrate, nitrite, ortho-phosphorus, condensed phosphorus, organic phosphorus, sulfate
- Rump and Krist (1988) – ammonium, boron, chloride, calcium, copper, magnesium, cyanide, iron, manganese, nitrate, nitrite, phosphorus compounds, potassium, silicic acid, sodium, sulfate, surfactants, zinc
• Vowles and Connell (1980) – ammonia, free chlorine
• Williams (2001) – ammonia, bicarbonate, carbonate, cations, chloride, iron, phosphate, potassium, sodium

6.2.5 Organics
• Harris (2001) – Kjeldahl nitrogen
• Ondrous (1993) – polyaromatic hydrocarbons
• Rump and Krist (1988) – Kjeldahl nitrogen, oils and fats, phenols
• Williams (2001) – phenols

6.2.6 Other
• Ondrous (1993) – total coliforms
• Pyatt and Storey (1999) – toxicity testing. This paper outlines a simple procedure that allows groups of students to investigate the toxic effects of potential environmental pollutants in the laboratory, using Daphnia magna as a test organism. The procedure introduces students to dose-dependant toxicity.
• Radojević and Bashkin (1999) – rainwater for pH, conductivity, chloride, nitrate, sulphide, cations (Na+, K+, Mg2+, Ca2+, NH4+)
• Parsons et al. (1984) - this manual serves as an introduction to the quantitative analysis of seawater. Biological and chemical techniques are described in detail, although, in general, the techniques require a minimum of prior professional training.

6.3 Analysis of atmospheric samples

6.3.1 General literature
• Boubel et al. (1994); Jones et al. (1999); Stern (1976)

6.3.2 Gases
• Harris (2001) – carbon monoxide in automobile exhaust
• Jaffe and Herndon (1995) – carbon monoxide in automobile exhaust
• Ondrous (1993) – oxides of calcium, carbon, magnesium, nitrogen, phosphorus, sulfur
• Radojević and Bashkin (1999) – ammonia, hydrogen chloride, nitrogen dioxide, ozone, sulfur dioxide
• Vowles and Connell (1980) – carbon monoxide, hydrocarbons, insecticides in cigarette smoke, nitrogen dioxide, total organic carbon

6.3.3 Particulate matter
• Harris (2001)- sulfur in coal
• Ondrous (1993) – particulates
• Radojević and Bashkin (1999) – aerosols for heavy metals and major constituents

6.4 Analysis of soils, sediments and sludges

6.4.1 General literature
• Brady and Weil (2002); Carter (1993); Cresser et al. (1995); Hesse (1971); Jones et al. (1999); Klute (1994); Mickelson (1998); Rowell (1994); Smith and Mullins (1991)

6.4.2 General parameters
• Radojević and Bashkin (1999) – bulk density, specific gravity, water content, loss-on ignition, particle size, conductivity, pH, redox potential, alkalinity
• Rowell (1994). – acidity, alkalinity, buffer capacity, density, loss-on ignition, hydraulic conductivity, pH, porosity, redox potential, shrinkage, stone content, stone density, texture, volume, water content, water potential, water release, soil water suction
• Williams (2001) – soil pH
6.4.3 Organics

- Radojević and Bashkin (1999) – organic matter, organic nitrogen
- Rowell (1994) – oxidisable carbon
- Rump and Krist (1988) – Kjeldahl nitrogen
- Vowles and Connell (1980) – grease, oils
- Williams (2001) – organic matter content

6.4.4 Inorganics

- Radojević and Bashkin (1999) – ammonia, cation exchange capacity, heavy metals (Al, As, Cd, Cr, Pb, Mn, Hg, Ni, Si, Zn), nitrate, nitrite, inorganic and organic phosphorus, sulfur
- Rump and Krist (1988) – ammonium, boron, chloride, phosphorus compounds, potassium, sodium, sulfate
- Rowell (1994) – available potassium, magnesium and calcium, calcium carbonate, cation and anion exchange capacity, nitrate, organic nitrogen, phosphate, soil organic matter, total metals
- Williams (2001) – cation exchange capacity

6.4.5 Other

- Radojević and Bashkin (1999) – chlorophyll
- Rowell (1994) – activity and respiration rate of microbial biomass, respiration rates

6.5 Analysis of vegetation

- Ondrous (1993) – arsenic in wood
- Radojević and Bashkin (1999) – ash, cations (Na+, K+, Mg++, Ca++), heavy metals, nitrogen, phosphorus, sulphur, water content

6.6 Analysis of environmental micro-organisms

6.6.1 General literature

- Primrose and Wardlaw (1982) – this large manual provides 111 experiments and exercises segregated under nine main headings. It is intended as a source book for lecturers rather than for students and provides a comprehensive sourcebook text for the teaching of microbiology. Chapter 6 contains 14 experiments on the activities and interactions of micro-organisms in environmental situations.
- Singh and McFeters (1992)
- O’Leary (1989)

6.6.2 Micro-organisms in drinking water

- Gleeson and Gray (1997) – includes standard methods for the enumeration of coliforms as well as alternative indicator systems for water quality analysis

6.6.3 Micro-organisms in water and wastewater

- Rump and Krist (1988) – includes a luminescent bacteria water test

6.7 Paper-based practical work

6.7.1 Problem-solving and mathematical exercises

- Wareham and Milke (2002) – water quality data

6.7.2 Project work

- Fialho et al. (1999) – spectrophotometry
- Vianna et al. (1999) – use of mini-projects
- Stefani and Tariq (1996) – group practical projects
6.8 Computer-based practical work

6.8.1 Virtual laboratory practicals

Peterson (2001) has suggested that many academics are fearful of the impact of online learning on traditional university learning, with fears focusing on the reduction of academic rigor and the separation of students from teachers, whilst Perley and Tanguay (1999) warn that the quality of education will suffer, with assembly-line delivery by people who are not course experts. On the other hand, Crow (1999) argues that online education is very similar to traditional teaching except that students and academics meet in virtual, rather than physical, spaces. Whatever the pros and cons, there appear to be few examples of virtual laboratory practicals available in Earth and Environmental Sciences at present. Two examples from other disciplines are listed below as a demonstration of what can be achieved when resources and time are made available.

Phil Marston at the University of Aberdeen has developed a self-contained online Virtual Laboratory ‘shell’ that includes an experiment to investigate the effects of sub-lethal copper contamination on *Gammarus duebeni*. This virtual laboratory can be visited at http://www.abdn.ac.uk/diss/ltu/pmarston/zoology/virtuallaboratory/nologin.php.

Robert Michel and his team (1999) at the University of Connecticut have developed the use of digital video clips for improved pedagogy and illustration of scientific concepts. Their article is available as an electronic publication in Spectrochimica Acta Electronica (Michel et al., 1999).

6.8.2 Other ideas

• Brattan et al. (1999) – experimental design and data analysis
• Cuttle et al. (1993) – creating courseware with MS Excel
• Nicholls (1998) – post-laboratory courseware
• Nicholls (1999) – pre-laboratory software
7 Resources for Teaching Disabled Students

Literature that provides advice and guidance for teaching laboratory experiments and instrumental techniques to disabled students in Earth and Environmental Sciences is scarce. However, you may obtain some ideas from the following papers.

This paper describes teaching methods used to teach a visually impaired student in an introductory geology course. Methods discussed include meeting with the student and making arrangements to provide all the handouts and syllabi for the course prior to the class; detailed planning of all lectures, class activities, and laboratory exercises; and a mechanism for providing feedback to the student.

This paper presents instructional tips for demonstrators and lecturers whose class includes deaf students from different educational backgrounds. Topics discussed include visual enhancement, writing and reading, speaking and class participation, and laboratory interactions.


A review of instructional practices in the classroom environment and science teaching in special education.


This paper includes strategies for teaching deaf students, and assessment of learning for students who are deaf and hard of hearing.


This brief paper discusses modifications to general education or introductory chemistry courses that allow visually-impaired students to participate productively. It describes a strategy for teaching about elements and density, and the construction of a conductivity tester for visually impaired students.


This paper offers guidelines for enhancing science instruction for students with disabilities by adapting, implementing, and assessing an activities-based approach. Salend's approach features a structured learning cycle, emphasis on the relationship of science to students' lives, experiential learning, inter-disciplinary themes, co-operative learning groups, instructional technology and multimedia, and evaluation of student performance.


Although this report is primarily aimed at school teachers, useful papers include ‘Integrating Students with Learning Disabilities into Regular Science Education Classrooms: recommended instructional models and adaptations’ by Katherine Norman and Dana Caseau and ‘Guidelines for Teaching Science to Students Who Are Visually Impaired’ by Benjamin Van Wagner.


A teacher shares three instructional aids that she used to teach blind as well as sighted students the basic principles of chemical bonding.


8 Internet Resources for the Earth and Environmental Sciences

About Chemistry
http://chemistry.about.com/
Provides information on a wide range of chemistry topics

American Chemical Society (division of Analytical Chemistry)
http://www.acs-analytical.duq.edu/

British Geological Survey
http://www.bgs.ac.uk/

British Mass Spectrometry website
http://www.bmss.org.uk/

British Standards Institute
http://www.bsi-global.com/

Centers For Disease Control and Prevention
http://www.cdc.gov/niosh/nnam/
A collection of methods for sampling and analysis of contaminants in the workplace air, and in blood and urine of workers who are occupationally exposed.

Chemsoc
http://www.chemsoc.org/
A division of the RSC providing a wide range of information for analytical scientists.

Extoxnet
http://ace.orst.edu/info/extoxnet/
Extoxnet provides a powerful tool for finding information on pesticides

GEsource
http://www.gesource.ac.uk/
Information resource for FE and HE in geography and the environment

Higher Education Academy Subject Centre for Geography, Earth and Environmental Sciences

Infra Red
http://www.ir-windows.com/

I-Mass
http://i-mass.com/
Provides Mass Spectrometry Journals, searches and articles of interest.

LC/GC Magazine
http://www.lcgcmag.com/lcgc/
The LC/GC website allows you to view articles that have been published in their magazine, providing useful information on these analytical techniques.

National Centre for Atmospheric Research
http://www.ncar.ucar.edu/

National Society for Clean Air and Environmental Protection
http://www.nsca.org.uk/

OSHA (Occupational Safety and Health Administration)
http://www.osha.gov/dts/sltc/methods/
Provides an alphabetical list of chemicals that have either a validated or partially validated OSHA method. (US Department of Labor)

PSIgate (Physical Sciences Information Gateway)
http://www.psigate.ac.uk/

Royal Society of Chemistry
http://www.rsc.org/lic/selectsites.htm
Provides useful links to a wide range of useful websitesinformation.

Sample Preparation
http://www.sampleprep.duq.edu/
This site concentrates on microwave digestion, but provides information on sample preparation with databases on acid decomposition.

Sigma Aldrich
http://www.sigmaaldrich.com/
Sigma-Aldrich provides some useful publications and application notes in the field of analytical chemistry. Use the literature search to find methods and techniques for analysis.

Spectroscopy Now
http://www.spectroscopynow.com/
Information on all spectroscopy techniques.

Spectroscopy
http://www.spectroscopy.co.uk/
General site on spectroscopy.

UK Department of the Environment, Transport and the Regions Food and Rural Affairs
http://www.defra.gov.uk/

UK Environment Agency
http://www.environment-agency.gov.uk/

UK National Environment Technology Centre
http://www.aeat.co.uk/

US Environment Protection Agency (EPA)
http://www.epa.gov/
The Environment Protection Agency (U.S.) website is useful to obtain information on methods for analysis of contaminants in the environment and information on pollutants.

US Geological Survey
http://www.usgs.gov/

Valid Analytical Methods
http://www.vam.org.uk/


9 References


Horobin, R., Andersen, B. and Williams, M. (1992) Active learning in practical classes, Effective Teaching and Learning in Higher Education Module 6, Parts 1 and 2, Sheffield: CVCP Universities’ Staff Development and Training Unit.


9.1 **Audio-visual materials**

9.1.1 **Videos**


9.1.2 **CD-ROMs**

Appendix 1. Student Induction to Laboratory and Practical Work – an example

Introduction
All students must attend an induction programme to laboratory and practical work on commencement of their studies. The induction programme should be carried out as soon as possible after the student commences their studies and attendance should be compulsory. It is essential that induction in key practical skills required for the studies is included in the programme.

Content of the induction programme
The induction programme should include general health and safety policies and procedures as well as key practical skills and should include information about:

- University and/or School/Department health and safety policy
- School/Department safety management, for example workplace health and safety officers, first aid officers, radiation officer, fire wardens, etc.
- Health and safety responsibilities of various persons within the School/Department, including students e.g. with regard to wearing of personal protective equipment, complying with health and safety instructions given by academic and technical staff, demonstrators, emergency personnel and first aiders
- Emergency procedures
- Accident/incident reporting procedures
- Personnel safety
- Building safety
- Working alone

An ES3-specific health and safety and laboratory induction should include information about:

- Policies, procedures, guidelines, information sheets, hazard alerts, etc. that are relevant to Earth and Environmental Sciences
- General laboratory safety
- Chemical safety
- Biological safety
- Radiation safety
- Use of particular equipment e.g. balances, fume cupboards, autoclaves, centrifuges, heating devices, etc
- Risk assessment and COSHH procedures

Records should be maintained in the School/Department of the type and level of induction attended by each student. Confirmation of attendance by the student should also be recorded.
**Student Safety Declaration Form**

Please complete the following checklist of issues that have been covered during the induction.

Student name: _______________________________  Student Number: ______________
School/Department: ___________________________

I confirm that I have received induction on the following issues:

- University and/or School/Department health and safety policy
- School/Department safety management
- Health and safety responsibilities of various persons within the School/Department, including students
- Emergency procedures
- Accident/incident reporting procedures
- Personnel safety
- Building safety
- Working alone
- Policies, procedures, guidelines, information sheets, hazard alerts, etc. that are relevant to Earth and Environmental Sciences
- General laboratory safety
  - Chemical safety
- Biological safety
- Radiation safety
- Risk assessment and COSHH procedures

The safe use of the following laboratory equipment has been demonstrated to me:

- Balances
- Fume cupboards
- Autoclaves
- Centrifuges
- Heating devices e.g. microwaves,
- Glassware
- Stirring and mixing devices
- Liquid nitrogen dispensing
- Other (specify)

Signed: __________________________ (Signature of student)    Date: ______________
Appendix 2. Storing and Handling Chemicals in the Laboratory

All chemical substances used in laboratories must be stored in safe conditions. Key issues that require consideration when storing chemicals are summarised below.

- Storage areas should be well ventilated and well lit.
- Suitable racking/shelving should be provided, which must be inspected regularly for signs of corrosion or weakening. Shelf coverings may be of value.
- Only the minimum amounts of chemicals required should be brought into the working area (although small quantities of commonly used substances can be stored appropriately in the laboratory).
- The chemicals must be suitably segregated to minimise risks of dangerous intermingling.
- Large containers of chemicals e.g. Winchesters, should only be carried in proper Winchester carriers. They should never be stored on floors, but on plinths about 4-8 cm high, to reduce the risk of them being knocked over.
- Spillage trays should be considered for corrosive chemicals e.g. concentrated acids.
- Suitable carriers for chemicals should be readily available.
- Stocks of chemicals should be date-stamped on receipt to facilitate stock rotation etc.
- Highly toxic substances must be stored in a locked store. Control must be exercised over the issues of these chemicals.
- Flammable substances - flash point below 32°C – must be stored in an approved fire resistant store to legislative requirements.
- Flammable liquids stored on benches for current use must be in containers not exceeding 500 cm$^3$ each.
- Stores for flammable liquids should be sited outside University buildings. In some situations, approved fire resistant bins and cupboards may be sited in or adjacent to the laboratory, providing the total quantity does not exceed 55 litres.
- The total quantity of flammable liquid held by a laboratory in store should not exceed one year’s usage.
- No other chemicals or materials must be kept in the flammable liquid store, bin or cupboard.
- If a refrigerator is used to store solutions containing flammable liquid, it must be free of internal electrical contacts. There must be no interior lights. All containers must be closed and labelled. Strict supervision of the use of refrigerators is essential.
- Some solids, such as sodium, potassium, white phosphorus, peroxides, etc, are inherently hazardous. They must be segregated from other chemicals and held in a fire resistant store or cupboard. Some chemicals in this category are damped down with water, oil or similar liquids to keep them safe. They should be regularly inspected in storage to ensure that they have not dried out.
- Gas cylinders not in use must be stored outside of University buildings, in a shady area, and suitably secure to prevent theft or damage.
- Gas cylinders used inside laboratories must have the name of the chemical appearing in legible form on the cylinder; a colour code is not sufficient designation. Gas cylinders must be securely held in an upright position (string, wire or similar makeshift materials are not acceptable) and must be located so that they are not exposed to direct flame or heat in excess of 125°F. Cylinders not in use must have the valve protective cap securely in place and must only be moved only in suitable handcarts.
Appendix 3. Storing and Handling Biological Materials in the Laboratory

The general principles of storing and handling biological materials are summarised below:

- All biological materials used in laboratories must be stored in safe conditions
- Only the minimum amounts of chemicals required should be brought into the working area
- Disposable laboratory gloves should not be worn in communal areas. Door handles, telephones, computer keyboards and mice (except in clearly labelled circumstances), lift buttons, etc. are not to be touched with gloves. If needed, wear one glove and use the ungloved hand to open doors, operate lifts etc. Rubber or disposable gloves should be worn when handling/working with: human blood or other body fluids; dangerous chemicals; infectious, or potentially infectious materials; UV light boxes; radioisotopes.
- Avoid ingesting micro-organisms. The best protection against ingesting micro-organisms is not to put them in your mouth. Labels and envelopes must not be licked. Pencils and pens must not be placed in the mouth. Chewing of fingernails, playing with hair, applying lipstick, eating, drinking, etc., are not allowed.
- Aerosol production should be minimised when carrying out work on an open bench. Use equipment designed to contain aerosols for all manipulations such as shaking, mixing or sonication. A period of five minutes is required after these manipulations to allow aerosols to settle. If appropriate, subculture organisms in biological safety cabinets. Place 'bench coat' or a similar absorbent paper over working surfaces and autoclave after use. Replace this regularly. Decontaminate work benches after spills and after work has been completed.
- When flaming wire loops, draw the loop gradually from the cooler to the hotter part of the flame to minimise spattering, or use electric heaters. Ensure the loop is completely closed and the loop wire is not longer than 6 cm. Disposable plastic loops must be placed loop-end down in disinfectant for 18-24 hours.
- Petri dish cultures of fungi should be sealed and incubated with the lid uppermost to prevent the dispersal of fungal spores. Recognise fungi as potential pathogens and be aware of the ability of some species to produce mycotoxins.
- Take care when handling Petri dishes that contain condensate. This may contain viable microorganisms that can be spread via droplets or aerosols when the plates are opened or dropped.
- Hands should be washed after completing each task and always before leaving the laboratory.
Appendix 4. General Safety Rules for Students

- Before performing any laboratory work, students should familiarise themselves with the layout of the laboratory and make a mental note of its specialist and safety features.

- Bags, coats or any other such items must be left in an identified location within the laboratory (e.g. clothing storage area, locker) or in a secure place outside the laboratory, ensuring that corridors/fire doors are not obstructed.

- Laboratory coats must always be worn in the laboratories and must be buttoned up. In addition, suitable clothing is necessary when working in a laboratory. Inappropriate clothing can be dangerous – loose sleeves can sweep flasks from the laboratory bench, sandals do not protect feet from spills, shorts and short skirts do not protect legs from chemical spills.

- Long hair must be tied so that it does not present a potential safety hazard.

- Safety goggles and gloves should be worn when appropriate. Wearers of spectacles or contact lens wearers should wear properly fitted goggles.

- No food or drink is allowed in the laboratory.

- Smoking is not allowed in the laboratory.

- Mobile phones are not normally allowed in the laboratory, except by prior consent from a tutor or a technician under exceptional circumstances.

- No unauthorised experiments are allowed in the laboratory. Pranks and other types of irresponsible behaviour have no place in laboratory areas.

- Chemical or biological safety data sheets must always be read before the practical. The instructions given for the handling, use and storage of all articles and substances, especially those chemicals that are flammable, toxic, explosive or radioactive, must be obeyed.

- Great care must be taken when handling and assembling glass apparatus. Broken glass must be disposed of in the special bins provided.

- When working with electrical equipment, take particular care to avoid introducing additional hazards due to liquid spillage etc. Always seek advice if you are not sure about electrical safety.

- Apparatus must not be set up and left unattended unless permission has been obtained and clear instructions are displayed indicating action to take in an emergency.

- Flasks, beakers etc. must be clearly labelled as to their contents in order to avoid potentially serious consequences.

- Laboratory chemicals must not be sniffed, inhaled or tasted. Mouth pipetting of chemicals is not allowed.

- All laboratory workers should avoid looking down the necks of flasks and test tubes or holding them above eye-level for examination. Awareness of the safety of others is needed when handling chemicals in glassware – the open neck of glassware should never point towards an individual.

- Hazardous chemical and biological spills on floors, benches or equipment should be reported to an appropriate member of staff and cleaned up immediately. Special treatment is required for spills of a bio-hazardous nature.

- Any faulty equipment should be reported to an appropriate member of staff and if necessary, removed from service for repair or disposal.

- All accidents and incidents must be reported immediately to an appropriate member of staff and recorded on an accident/incident report form.

- Throughout and at the end of a practical, the working area should be cleaned and tidied. Glassware should be rinsed and left to dry on a drying rack or tray; chemicals should be stored safely and equipment should (normally) be switched off. (Be aware that some items of equipment should never be switched off – ask if unsure.) Hands should always be washed before leaving the laboratory.
Appendix 5. Examples of Hazard Warning Symbols

Corrosive (chemical causes burns if it comes into contact with skin)

Highly flammable (can easily catch fire)

Toxic (could cause harm if the chemical comes into contact with skin, if ingested or if vapours are breathed in)

Harmful to the environment (will cause harm to living organisms if released into the environment)

Irritant (damages skin or eyes if they come into contact with the chemical)

Explosive (chemical could cause an explosion)

Carcinogen (chemical can cause cancer if it comes into contact with the body or is ingested)

Radiation (material is radioactive and gives off ionising radiation)

Biohazard (infectious substances)

Note: Hazard may be defined as the ability of an activity or a substance to cause harm. Hazards may cause injury to people or damage property and the environment.
Appendix 6. Accident Report Form – an example

ACCIDENT/INCIDENT REPORT
(to include injury, near-miss, dangerous occurrence, occupational ill-health and violence at work)

General details of the incident
Date ..............................................................................................................................
Time .........................................................................................................................am/pm.

Building and room or place.....................................................................................................................

1. Person involved
   (a) Name in full: Surname ..........................................................................................
       First names ..............................................................................................................
   (b) Private address ....................................................................................................
       ............................................................................................................................
       Postcode .................................................................................................
   (c) Occupation.........................................................................................................
   (d) University: Employee □  Student □  Visitor □  Contractor □
       (tick as appropriate)
   (e) Department ........................................................................................................
   (f) Male □  Female □
   (g) Age at last birthday.................................

2. Nature and site of injury (if to a limb or eye, state whether right or left).
   ..................................................................................................................................
   ..................................................................................................................................

Is a claim to be made to the Department for Work and Pensions for Industrial Injuries Benefit?
   YES □  NO □

4. Nature and cause of incident
   (a) Work or process being performed ........................................................................
       ............................................................................................................................
   (b) Nature of accident ..............................................................................................
       ............................................................................................................................
   (c) Cause, if known ......................................................................................................
       ............................................................................................................................

5. First-Aid if any, with name of person giving assistance
   .....................................................................................................................................
6. Hospital treatment for more than 24 hours   Yes  No

7. Absence from work for more than 3 days   Yes  No

8. Name and address of any witness

..................................................................................................................................................................................................................

..................................................................................................................................................................................................................

9. Name of person making this report

..................................................................................................................................................................................................................

Address

..................................................................................................................................................................................................................

Occupation

..................................................................................................................................................................................................................

10. Date of report

..................................................................................................................................................................................................................

11. Signature of immediate Supervisor or person in charge

..................................................................................................................................................................................................................

IMMEDIATE SUPERVISOR TO COMPLETE PART II BELOW

12. Give full account of the incident explaining how it happened, and how injuries were received. Give names and
type of plant, machinery or vehicle involved and state whether it was in motion. What was (were) the
person(s) involved doing at the time of the accident? If a fall occurred, how far?

13. Had a risk assessment been carried out for the process/activity?

Yes  No

14. Had person(s) involved received training or instruction in the work or activity being carried out?

Yes  No

Was there any supervision of the work or activity being carried out?

Yes  No

16. Action taken to prevent recurrence (e.g. switched off power, cleaned floor)

..................................................................................................................................................................................................................

17. At the time of the incident was the person(s) authorised for the purpose of his/her/their work to be where
he/she was (they were) : Yes  No

to be doing what he/she was (they were) doing: Yes  No

The report must be completed within 24 hours and sent to the Health and Safety Adviser. If the full names and
addresses are not known to the informant, they will be added by the Safety Office with the help of Registry or the
Human Resources department.
# Appendix 7. COSHH Form – an example

## COSHH ASSESSMENT

(Product Safety Data Sheet to be attached to this assessment)

<table>
<thead>
<tr>
<th>Dept. / Location</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 1. Product Information

<table>
<thead>
<tr>
<th>Product (trade name)</th>
<th>Sodium chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Type/Size</td>
<td>Various</td>
</tr>
<tr>
<td>Description</td>
<td>Flowing white powder</td>
</tr>
<tr>
<td>Use</td>
<td>Various laboratory experiments</td>
</tr>
<tr>
<td>Users</td>
<td>Various (academic staff, technicians, students)</td>
</tr>
</tbody>
</table>

### 2. Toxicity (tick box)

- [ ] Very Toxic
- [ ] Toxic
- [ ] Harmful
- [ ] Corrosive
- [ ] Sensitising
- [x] Irritant

Health Hazards: .................................................................

### 3. First Aid Procedures

- Eyes: Flush with water for at least 15 minutes. Get medical aid.
- Skin: Flush skin with soap and water for 15 minutes. Get medical aid if irritation continues.
- Ingestion: Do not induce vomiting. Give 2-4 cupfuls of milk or water.
- Inhalation: Remove to fresh air. Give oxygen if breathing difficult.

### 4. Control Measures

- [ ] Training
- [ ] Exposure monitoring
- [ ] Health surveillance
- [ ] Fume cupboard
- [ ] Local exhaust ventilation
- [ ] Gloves
- [ ] Safety glasses
- [ ] Safety goggles
- [ ] Dust mask
- [x] Overalls/lab coat
- [ ] Other respiratory protection

### 5. Others:

### 6. Fire

- Is substance flammable? No
- Explosive? No

### 7. Extinguisher to be used

- [x] Water
- [x] Foam
- [ ] Powder
- [x] CO₂

### 8. Disposal Procedures

To non-acid waste.

### 9. Comments and Risk Assessment

<table>
<thead>
<tr>
<th>10. Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>To be completed by:  J Bloggs  Date:</td>
</tr>
<tr>
<td>Risk Rating:  LOW  MEDIUM  HIGH</td>
</tr>
<tr>
<td>Signature:  Date:</td>
</tr>
</tbody>
</table>
### Additional Information

<table>
<thead>
<tr>
<th>Details of Exposure Monitoring:</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintenance of Control Measures:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Health Surveillance Details:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Label with precautionary measures. Irritating to eyes. In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual Review History (Date and Signature)</th>
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</tbody>
</table>
Appendix 8. Hazard Identification and Risk Assessment (HIRA) Form – an example

A.9.1 Demonstration of AAS to first year undergraduate students

Form HS1 Ref. No: ........................................

UNIVERSITY OF MIDSHIRE

PART 1. HAZARD IDENTIFICATION
(to be completed by the Faculty/Service/Department Safety Adviser).

1) Title of Activity/Equipment Location (Building/Room)
   Calibration using copper standards (1 to 5 ppm) using Atomic Absorption Spectrophotometer (flame)

2) Brief Description of the Activity/Equipment (under assessment).
   Demonstration of AAS to First Year undergraduate students

3) Persons Affected
   (list all persons in your area, either staff or non staff who may perform the activity or use the equipment).
   a) Staff: (names, if possible, job titles plus numbers if not).
      Staff operating the equipment, plus any technicians present.
   b) Non Staff: (inc. students (numbers, i.e. per year/per practical, etc.), visitors and general public).
      First year students.

4) Potential Significant Hazards (list all hazards associated with the activity or equipment).
   Providing the equipment is operated correctly, there are no potential significant hazards under normal laboratory operating conditions.
   Causes for concern include:
   - Flame/hot gases
   - Compressed gases (air and nitrous oxide)
   - Flammable gases (acetylene)
   - Explosive air/gas mixture
   - Toxic fumes
   - UV radiation
   - Electricity

Signed: ...................................................... (Safety Adviser/Risk Assessor)  Date:......................................................
### PART 2. RISK ASSESSMENT (to be completed by relevant Dean or Head)

Risk = likelihood (of event occurring) \* hazard (severity)

Using the definition of risk which covers both likelihood (chance) of occurrence and severity of harm (taking into account population at risk and level of injury possible) calculate the risk by grading the likelihood (1-4) and the severity (1-4), (1 = Low, 4 = High), giving a final figure between 1 and 16.

<table>
<thead>
<tr>
<th>Hazard Identified</th>
<th>Likelihood of occurrence (grade 1-4)</th>
<th>Hazard (severity) (grade 1-4)</th>
<th>Risk (likelihood x hazard) (A x B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flame</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Hot surfaces</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Compressed air</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Acetylene</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Electricity</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>UV radiation</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Toxic fumes</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cu standards</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Signed: .......................................................... Dean/Head of Department/Service

Date: ........................................................
## PART 3. CONTROL MEASURES

### a) EXISTING (list all controls that are existing in place)

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flame</td>
<td>Staff are aware of the potential hazards and will issue warnings to students who may inadvertently move too close to the equipment</td>
</tr>
<tr>
<td>Hot surfaces</td>
<td></td>
</tr>
<tr>
<td>Compressed air</td>
<td></td>
</tr>
<tr>
<td>Acetylene</td>
<td></td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
</tr>
<tr>
<td>UV radiation</td>
<td></td>
</tr>
<tr>
<td>Toxic fumes</td>
<td></td>
</tr>
<tr>
<td>Protective clothing</td>
<td></td>
</tr>
</tbody>
</table>

Existing Controls Satisfactory? **YES** *(if NO parts b) and c) must be completed)*

### b) SHORT TERM REQUIREMENTS (implementation within six months)

<table>
<thead>
<tr>
<th>Date</th>
<th>Date</th>
</tr>
</thead>
</table>

### c) LONG TERM REQUIREMENTS (implementation within six to eighteen months)

<table>
<thead>
<tr>
<th>Date</th>
<th>Date</th>
</tr>
</thead>
</table>

Signed as Completed: ......................................................... Dean/HOS/HOD  Date: ..............................................

Comments: Original to be kept by Faculty/Department/Service

Assessment review date: Annual
PART 4. NOTIFICATION OF CHANGES

(To be completed by Line Manager and Risk Assesser)

Any significant change to the working activity or equipment must be suitably assessed.

1) Description of Changes to Activity/Equipment *(Brief details only)*

2) New Potential Hazards Associated with Changed Activity/Equipment

3) Control Measures to be Implemented

Signed:  .................................................................  Dean/HOS/HOD  Date:  .................................
A.9.2 River water sampling (for subsequent laboratory analysis by undergraduate students)

Form HS1

Ref. No: ..............................

HAZARD IDENTIFICATION AND RISK ASSESSMENT (HIRA) FORM

PART 1. HAZARD IDENTIFICATION
(to be completed by the Faculty/Service/Department Safety Adviser).

1) Title of Activity/Equipment Location (Building/Room)
   River water sampling (for subsequent laboratory analysis by undergraduate students)

2) Brief Description of the Activity/Equipment (under assessment).
   Undergraduate students undertaking sampling and site inspection as part of module ES2
   • Taking river water samples
   • Site inspection
   • Transportation and storage of samples

3) Persons Affected
   (list all persons in your area, either staff or non staff who may perform the activity or use the equipment).
   a) Staff: (names, if possible, job titles plus numbers if not).
      J. Bloggs, Senior Lecturer
      A. N. Other, technician
   b) Non Staff: (inc. students, (numbers, i.e. per year/per practical, etc.), visitors and general public).
      2nd Year Undergraduate students (14)

4) Potential Significant Hazards
   (list all hazards associated with the activity or equipment).
   • Slips, trips and falls on uneven or slippery surfaces and steps
   • Falling into watercourse
   • Hit by mobile plant and vehicles
   • Contact with bacteria, pathogens, vermin
   • Exposure to dangerous chemicals
   • Confrontation with aggressive persons
   • Exposure to needles and sharp objects
   • Injury from lifting
   • Asphyxiation in confined spaces
   • Hit or trapped by moving machinery

Signed: ................................................................. (Safety Adviser/Risk Assessor) Date:.........................................................
**PART 2. RISK ASSESSMENT (to be completed by relevant Dean or Head)**

\[
\text{Risk} = \text{likelihood (of event occurring)} \times \text{hazard (severity)}
\]

Using the definition of risk which covers both likelihood (chance) of occurrence and severity of harm (taking into account population at risk and level of injury possible) calculate the risk by grading the likelihood (1-4) and the severity (1-4), \((1 = \text{Low}, \ 4 = \text{High})\), giving a final figure between 1 and 16.

<table>
<thead>
<tr>
<th>Hazard Identified</th>
<th>Likelihood of occurrence (grade 1-4)</th>
<th>Hazard (severity) (grade 1-4)</th>
<th>Risk (likelihood x hazard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slips, trips and falls on uneven or slippery surfaces</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>and steps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Falling into watercourse</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Hit by mobile plant and vehicles</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Contact with bacteria, pathogens, vermin</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Exposure to dangerous chemicals</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Confrontation with aggressive persons</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Exposure to needles and sharp objects</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Injury from lifting</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Asphyxiation in confined spaces</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Hit or trapped by moving machinery</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Signed: .................................................................................................................. Dean/Head of Department/Service Date: ..........................
## PART 3. CONTROL MEASURES

### a) EXISTING (list all controls that are existing in place)

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slips, trips and falls on uneven or slippery surfaces and steps</td>
<td>Wear safety footwear. Do not climb steep surfaces whilst carrying bottles or equipment. Be aware of risk of sampling from high above water level.</td>
</tr>
<tr>
<td>Falling into watercourse</td>
<td>Always work in pairs. Wear a lifejacket.</td>
</tr>
<tr>
<td>Hit by mobile plant and vehicles</td>
<td>Wear high visibility clothing. Keep to marked footpaths where possible. If a sampling point is close to a road, extra care must be taken.</td>
</tr>
<tr>
<td>Contact with bacteria, pathogens, vermin</td>
<td>Wear safety gloves when taking samples.</td>
</tr>
<tr>
<td>Exposure to dangerous chemicals</td>
<td>Wear safety glasses when using syringes or bottles containing preservatives.</td>
</tr>
<tr>
<td>Confrontation with aggressive persons</td>
<td>Avoid confrontational situations.</td>
</tr>
<tr>
<td>Injury from lifting</td>
<td>Obey manual handling guidance.</td>
</tr>
<tr>
<td>Exposure to needles and sharp objects</td>
<td>Wear safety footwear.</td>
</tr>
<tr>
<td>Asphyxiation in confined spaces</td>
<td>Do not enter confined spaces.</td>
</tr>
<tr>
<td>Hit or trapped by moving machinery</td>
<td>Avoid moving machinery</td>
</tr>
<tr>
<td>General control measures</td>
<td>Do not eat, drink or smoke on site. Ensure samples are sealed and secured in vehicles. Observe written and oral guidance provided by staff. Staff should carry a mobile telephone and leptospirosis card.</td>
</tr>
</tbody>
</table>

Existing Controls Satisfactory? YES (if NO parts b) and c) must be completed)

### b) SHORT TERM REQUIREMENTS (implementation within six months)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Implementation Date</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensure all persons involved read risk assessment.</td>
<td>Before visiting site</td>
<td></td>
</tr>
<tr>
<td>Ensure all persons involved have received some manual handling guidance.</td>
<td>Before visiting site</td>
<td></td>
</tr>
<tr>
<td>Check all persons involved in sampling have appropriate personal protective equipment (PPE).</td>
<td>Before visiting site and at site</td>
<td></td>
</tr>
</tbody>
</table>

### c) LONG TERM REQUIREMENTS (implementation within six to eighteen months)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Implementation Date</th>
<th>Completion Date</th>
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<td></td>
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