

Teaching Practical Skills for Science

Cambridge International AS & A Level Sciences

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**Introduction**

Practical work is an essential part of science. Scientists use evidence gained from prior observations and experiments to build models and theories. Their predictions are tested with practical work to check that they are consistent with the behaviour of the real world. Learners who are well trained and experienced in practical skills will be more confident in their own abilities. The skills developed through practical work provide a good foundation for those wishing to pursue science further, as well as for those entering employment or a non-science career.

The science syllabuses address practical skills that contribute to the overall understanding of scientific methodology. Learners should be able to:

1. **plan** experiments and investigations
2. **collect**, record and present observations, measurements and estimates
3. **analyse** and interpret data to reach conclusions
4. **evaluate** methods and quality of data, and suggest improvements.

The practical skills established at AS Level are extended further in A Level. Learners will need to have practised basic skills from the AS Level experiments before using these skills to tackle the more demanding A Level exercises. Although A Level practical skills are assessed by a timetabled written paper, the best preparation for this paper is through extensive hands-on experience in the laboratory.

The example experiments in the 12 Practical Booklets for each of the three AS and A Level science subjects, available on Teacher Support (<http://teachers.cie.org.uk>), can form the basis of a well-structured scheme of practical work for the teaching of AS and A Level science. The experiments have been carefully selected to reinforce theory and to develop learners’ practical skills. The syllabus, scheme of work and past papers also provide a useful guide to the type of practical skills that learners might be expected to develop further. About 20% of teaching time should be allocated to practical work (not including the time spent observing teacher demonstrations), so this set of experiments provides only the starting point for a much more extensive scheme of practical work.

**Development of practical skills**

AS Level skills

The syllabus shows how these four skills of planning, collection, analysis and evaluation are assessed and the structure is common to all three sciences. The emphasis of the AS Level syllabus is on developing an understanding of, and gaining practice in, scientific procedures, the collection of data, and analysis and drawing conclusions. It also starts to develop critical evaluation of procedures by suggesting improvements to experimental methods. In general, learners find that the first two skills, those of carrying out practical procedures and collecting data, more straightforward and easier to undertake than analysis, whilst evaluation is least readily accessed at this level.

Learners will become competent in these skills through practical experience. During the AS Level course they should be expected to carry out as much practical work as possible, since this will develop key practical skills and enhance their motivation, as well as their understanding of the theory part of the course. The syllabus clearly describes the skills that are to be assessed and should be used to ensure that activities are appropriately targeted.

Teaching learners to manipulate, measure, estimate and observe

As part of their AS Level studies, learners will be expected to develop skills in manipulating and measuring using standard laboratory apparatus. These will form a basis on which more advanced manipulative skills will be developed during the A Level course. During their AS Level course it is assumed that learners will develop their skills in order to measure accurately and to manage their time effectively, so that they are confident in their use of apparatus.

* Various investigations will also allow learners to collect data and make observations. This will require that learners are able to follow a set of instructions and set up apparatus appropriately. They should then be able to collect data using a wide variety of means.
* Learners should be able to make informed decisions about the number of times a reading should be taken and the range of readings that is required to collect reliable and valid data. Learners should also be able to replicate readings or observations as necessary.

Teaching learners to present data and record observations

Many learners do not find this an easy skill to master. It is important that learners can record data so that it is capable of being understood by others. This requires skill in deciding how to present the data and what should be recorded.

* Learners need to be able to present numerical data in tables and to decide on the structure of the table and what titles and units should be written in the column headers. They should design the table so that readings from the investigation can be entered directly into it as the readings are taken. Space should be allocated in tables as necessary for calculated values and deductions.
* Learners should ensure that all readings are taken with the same degree of accuracy and precision.
* Learners often assume that everyone understands how they achieved their answers to questions or calculations without realising that this is not the case. This is particularly true when answering examination questions. Learners should be encouraged to display their calculations and reasoning, as well as use the correct number of significant figures for calculated quantities.
* Learners should be able to choose a suitable method of presenting data obtained from an investigation. For example, quantitative data as graphs, qualitative data as tables and cellular and histological data as drawings.
* When producing graphs, learners should be able to select which variables to plot on the x and y axes. They should be able to plot with accuracy.
* More information concerning the presentation of data and observations is provided in the syllabus.

Teaching learners to analyse, interpret data, draw conclusions and evaluate

These are the hardest skills that have to be mastered by learners. Evaluation, in particular, is found to be very difficult by most learners, as they have to think in the abstract rather than handle real apparatus and materials. It is important that the basics in these skills are mastered so that they can be developed further in the A Level course.

* Learners need to be able to interpret data or observations by describing patterns and trends shown in tables and graphs. In data such as highly curved graphs, the key patterns should be described, and in data which produces simple curves or straight lines, the trend of the data should be observed and described.
* Learners should be able to determine unknown values by extrapolation and interpolation (or estimation) of lines on graphs, and be able to calculate the mean from replicated observations.
* It is important that learners are able to explain the degree of confidence they have in their conclusion and identify and explain possible sources of error in the investigation.
* Learners should be able to say whether the data obtained supports the original hypothesis or not, and use this to make further predictions.
* The ability to make simple evaluations should be practised so that this skill can be further developed in the A Level course. This enables learners to suggest improvements to procedures so as to improve the reliability of the data obtained and to extend investigations into new situations or solve related problems. The more practice learners have of this skill, the better prepared they will be. Ideally, every investigation could be evaluated using a simple checklist until it becomes an automatic response by a learner.

A Level skills and extending AS Level skills

The A Level syllabus builds upon the practical skills developed at AS Level. Its emphasis is on the higher-level skills of planning, analysis and evaluating. In order to plan effectively, learners need to be able to evaluate procedures and critically assess results. This is best achieved by the completion of the practical exercises starting in AS with relatively straightforward and familiar contexts and developed at A Level by the use of more complex procedures and less familiar contexts. Data analysis again develops from AS Level into more complex treatments, so that learners need to be given opportunities to gather suitable data and perform the appropriate manipulations. The evaluation of conclusions and assessing procedures are very high-order skills. Learners who have not had sufficient opportunity to plan and trial their own investigations will find these skills difficult. Learners are not expected to be able to plan perfectly, but to recognise weaknesses and make reasonable suggestions for improvement. The best learning tool to develop these skills is to devise a plan, carry out the investigation and then assess how well the planned procedure worked.

The A Level skills build on the AS Level skills already developed by learners. It cannot be emphasised enough that learners will not become competent in these skills without practical experience.

* AS Level practical skills will be extended by more complex investigations and the use of more specialised apparatus. In some sections of the syllabus there will be many unfamiliar techniques and quite complex equipment. It is important that learners gain confidence in the use of the apparatus and understand how it works. It is anticipated that teachers will develop practicals into opportunities for learners to evaluate or plan exercises.
* The analysis and evaluation will also be more extensive. Analysis data will involve calculations and statistical testing.

Teaching learners to evaluate methods

Evaluation refers to a number of skills concerned with the design of an experiment; essentially ‘how well did the experiment work’. Learners should question the way in which a procedure is carried out, comment on the reliability of the results and understand the limitations of a method. Learners need to acquire these skills before they can progress to the high order A Level skill of planning. The more practice learners have, the better prepared they will be. Ideally, every investigation could be evaluated using a simple checklist until it becomes an automatic response by the learner.

* At AS Level, learners will have been taught to evaluate procedures and suggest improvements. These skills will be utilised at A Level and developed into the higher order skills recognising the cause of anomalous and contradictory results and determining how a procedure can be modified to remove potential sources of error. The skill of evaluation is further developed by learning how to assess results in relation to the stated aim or hypothesis of the investigation.
* Learners need to be able to judge the reliability of their results. Many learners confuse reliability (consistent repeatable results with accuracy) with measuring using the appropriate equipment. One strategy is to compare class results, or actual results, to theoretical results. Once the reliability is known, learners can then relate to the aim of the experiment. To develop these skills learners need to be encouraged to question. Initially, learners could use a checklist of questions such as: Do I have enough results? How much variability is there in my results? How many results are anomalous? How accurate was the equipment used? Have all the variables been controlled, if not, what should I do to improve this? How else could I have measured? Do my results support the aim/hypothesis, if not, which part and how can I change the procedure?

Teaching learners to plan experiments and investigations

Planning the experiment requires learners to formulate a hypothesis, recognise variables and determine how to test a hypothesis. Learners cannot access these skills without familiarity with experimental procedures and experience of using apparatus. Skills that are apparently straightforward, such as choosing suitable apparatus and devising an appropriate procedure, become problematic as learners are uncertain what to measure or how to measure. Awareness of safety does not really develop unless learners are actively involved in activities that involve a potential risk. It is expected that learners will be encouraged to use safety information sources, such as hazard cards, e.g. Hazcards from CLEAPSS.

* Evaluation skills are a starting point for planning. At a preliminary level this may be to modify an existing procedure to generate more reliable results. To develop this skill further, learners could be given the task of producing a plan for an investigation using an existing experimental set for a different purpose.
* To design their own experiment, learners initially need to be in a familiar context. It is helpful to have a checklist to prevent critical features of the plan from being omitted. Devising a generic checklist by learner participation can help to clarify the principles of planning as required by the syllabus learning outcomes. This could be a list of questions or a worksheet to complete. Initially, teachers may choose to give a hypothesis and ask the learners to devise a plan.
* Once learners have reached the stage of planning their investigations, it is essential that they try them out. Often plans do not work as anticipated, so learners need to evaluate and refine their plans. It is common for learners to make unrealistic choices of apparatus and quantities, but unless they are given the opportunity to try they remain unconvinced. Learners should be encouraged to use the apparatus available, which may limit the syllabus contexts from which planning exercises may be drawn.
* The plans produced by learners are, by their nature, different from each other. If the same hypothesis is being tested then there may be similarities. However, once learners devise their own hypotheses there may well be significant differences. This has implications for both resources and supervision. One strategy mentioned in the section on delivering practical skills is to incorporate planning into a circus of activities, particularly if resources are limited. However, planning and evaluation do not need to be carried out in the laboratory, they could be carried out in a classroom. For example, planning in a lesson beforehand, trialling in a laboratory and evaluating as homework or as a follow-up classroom activity. Another issue to consider is the preparation time for learner-planned activities. As part of their plan, learners should produce an equipment list, with quantities, that can be provided to the lab technician (or other person responsible for the preparation). For standard laboratory equipment, learners should know where the equipment is stored and be able to get it for themselves, but the person responsible for resources will need to know the overall requirements to ensure that there is sufficient available during the practical.

**Ways of doing practical work**

In planning a scheme of practical work it is important to consider a variety of approaches which include those that allow learners to work independently.

Some practical activities should follow the well-established structure which includes learners following a detailed protocol. Such well-structured learning opportunities have a vital role to play in introducing new techniques, particularly in rapidly developing fields. In these new areas of science, teachers will often find themselves leading practical work that they have to trial themselves beforehand.

Other practical activities should offer learners the opportunity to devise their own methods, or to apply methods that they have been taught, to solving a problem. Exposure to new and unfamiliar techniques often provides a stimulus to engage learners’ interest and challenge their thinking.

Practical activities may be used as a tool to introduce new concepts or used to support and enhance required knowledge and understanding. In all cases, learning will be enhanced most effectively by practical work that encourages learners to be involved and to think, and to apply and use their knowledge, understanding and skills.

Practical work does not always have to be laboratory based. In classrooms, the use of models, role-play and paper cut-outs to simulate processes can be equally valuable. Field studies also contribute greatly to a learners’ appreciation of science and their motivation and enjoyment of the subject, which no amount of reading or watching videos can replace.

There are a variety of strategies by which practical work can be integrated into a programme of study. Teachers should use a number of different methods, enhancing a variety of subject-specific skills and simultaneously developing a range of transferable skills that will be useful throughout their future professional lives. Some of the ways of delivering practical work also enable the teacher to interact on a one-to-one basis with individual learners. This allows a teacher to offer support at a more personal level and develop a greater awareness of an individual learner’s needs.

Your choice of the specific strategy to use will depend on such issues as class size, laboratory availability, the availability of apparatus, the level of competence of your learners, availability and expertise of technical support, the time available, your intended learning outcomes for the activity and safety considerations.

The following are some possible strategies for delivery of practical work.

Teacher demonstrations

These require less time than a full class practical, but give little opportunity for learners to develop manipulative skills or gain familiarity with equipment. Careful planning can give opportunity for limited learner participation. Teacher demonstrations are a valuable way of showing an unfamiliar procedure at the start of a practical session, during which learners go on to use the method.

Considerations in choosing to do a demonstration might include:

* **Safety** – some exercises carry too high a risk factor to be performed in groups
* **Apparatus** – complicated procedures or those using limited resources
* **Time** – demonstrations usually take less time
* **Outcome** – some results are difficult to achieve and may be beyond the skill level of many learners. A failed experiment may be seen as a waste of time
* **Learners’ attention** – a danger is that the attention of some learners will drift
* **Manipulative experience** – the teacher gets experience, the learners do not.

There are many good reasons for the teacher to perform a demonstration but be aware that most learners have a strong preference for hands-on experimentation. Wherever possible, let them do it.

Group work

**Whole class practical sessions**. These have an advantage in terms of management, as all learners are doing the same thing. Learners may be working individually, in pairs or in small groups. Integrating this type of practical is straightforward as the lessons beforehand can be used to introduce the context and the following lessons can be used to draw any conclusions and develop evaluation. Where specialised equipment or expensive materials are in short supply this approach may not be feasible.

**Small group work.** This can provide a means of utilising limited resources or managing investigations that test a range of variables and collect a lot of measurements. Although the same procedure may be performed, each learner group collects only one or a few sets of data which are then pooled. For example, if five concentrations of the independent variable are being tested, each of which need to be measured at two minute intervals for thirty minutes, then a group of five learners can each test one concentration. Field studies also lend themselves to group activities as a lot of data has to be collected in a short period of time. The individual learner has the opportunity to develop their subject-specific skills. Part of the role of the teacher is to monitor and maintain safety and also to enable and persuade reluctant learners to take part. Group work supports personal development as learners must interact and work co-operatively.

Considerations in choosing group work might include:

* **Learning** – successful hands-on work will reinforce understanding; also, learners will learn from each other
* **Confidence** – this will grow with experience
* **Awareness/insight** – should grow with experience
* **Team building** – a desirable outcome.
* **Setting out** – all learners doing the same thing is easier for the technicians
* **Confusion** – incomplete, ambiguous or confusing instruction by the teacher will waste time while the instructions are clarified but may also compromise safety and restrict learning
* **Opting out** – some learners will leave it for others to do and so learn very little
* **Safety** – this could be a serious issue and constant vigilance is essential
* **Adaptation** – the urge to adapt their experiments, to ‘see what would happen if’, must be strictly dealt with
* **Discipline** – practical time must not be allowed to become ‘play time’.

Working in groups, whether as part of a whole-class practical session or where groups are working on parts of a whole, is probably the preferred option for many learners. At A Level, it is highly desirable to include opportunities for learners to work on their own, developing their own skills and independence.

Circus of experiments

A circus comprises a number of different exercises that run alongside each other. Individual or groups of learners work on the different exercises and, as each exercise is completed, move on to the next one. In this way, limited resources can be used effectively.

There are two basic approaches. Most commonly, during a lesson a number of short activities are targeted at a specific skill. Alternatively, over a series of lessons, a number of longer practical activities are used, addressing a variety of skills. The circus arrangement may be more difficult to manage as learners are not all doing the same activity. This puts more pressure on the teacher as they have to cope with advising and answering questions from a variety of investigations. With circuses spread over a number of sessions, careful planning is needed to enable the teacher to engage each group of learners, to maintain a safe environment. In these situations it is useful to have at least two of the circus activities that involve no hands-on practical work; such as using data response based simulations or other activities. In this way, the teacher can interact with groups that need a verbal introduction or short demonstration and can monitor their activities more effectively.

Considerations in choosing to do a circus of experiments might include:

* **Apparatus** – if the amount of apparatus used in an exercise is limited, learners are able to use it in rota
* **Awareness** – by observing their peers, learners will become more aware of the pitfalls of the exercise and so will learn from the experience of others
* **Safety** – different exercises may carry different safety risks, all of which would need to be covered.
* **Setting out** – learners doing different exercises will make it more difficult for the technicians
* **Opting out** – some learners may be tempted to ‘borrow’ the results of earlier groups.

Within theory lessons

This option should be considered whenever it is viable. It is likely that the practical work would be by demonstration, as this would take less time. Given the power of visual images, the inclusion of a short practical to illustrate a theoretical point will reinforce that point and so aid the learning process. It is critical, however, that the practical works correctly, otherwise the flow of the lesson is disrupted and confidence in the theory may be undermined. The exercise should therefore be practiced beforehand.

Project work

Projects are a means by which a learner’s interest in a particular topic, which is not always directly on the syllabus, can be used to develop investigative skills. It can also be used to access parts of the syllabus that have little laboratory-based investigation. For example, learners might use internet research to find examples of a particular topic and present a poster display showing their findings. This sort of investigative work can be individual, or a group activity. Once the project is underway, much of the work can be learner based outside the classroom. Care is needed in selecting the topics and setting a timescale, so that the relevance is maintained to the syllabus context. The work can be directed at the production of posters, presentations or reports from groups or individuals.

Extra-curricular clubs

The role that these can play is in stimulating scientific enquiry methods. There are a number of ways of using clubs. One way is to hold the club session during the teaching day so that all learners can attend. In effect this becomes additional lesson time in which learners can practice investigative skills, including laboratory work. Such lab work involves materials that have a cost, which must be planned for beforehand. If the club is held outside the teaching day it should be voluntary as not all learners will be able to attend, and so syllabus-specific activities should be limited unless they are repeated during school time. After-school clubs could be a vehicle for project work that is related to science and of social or economic importance, for example, endangered species or local mineral resources. Learners who do attend the club could be used as a teacher resource by bringing back their finding to a classroom session.

**Developing good practice in practical work**

Learners often find it a problem to integrate the practical work to the theory. This is particularly true when a series of experiments or a long-term investigation or project is undertaken. Some potential issues include:

* Some learners use odd scraps of paper in the laboratory, which can be lost or become damaged or illegible if liquids are spilled on them. It is important that learners record results immediately and accurately and take care of them.
* Practical procedures may be provided, or learners write their own notes from a teacher demonstration. These may be lost, so learners end up with results but no procedure or context.
* When results take a period of time to collect, analysis becomes isolated from the context of the investigation and may not be completed.

The key to minimising these issues is to ensure learners are encouraged to follow good working practices. This is also vital for learners with specific learning difficulties that affect their ability to organise their work.

Learners could keep all of their practical work together or integrate it within the relevant theory notes. If learners are using folders to keep their (paper-based) theory notes together, the practical hand-outs and write-ups can be easily integrated into the appropriate area. Where learners keep a separate practical book, learners should be encouraged to glue provided protocols and their laboratory records into the book so that they are not lost. Depending on how they learn, individuals may vary in their preferred method. Whichever option is chosen, learners need to be encouraged to relate their investigations to the appropriate theory and to regard it as something that needs to be thoroughly assimilated.

Considerations for developing good practice in practical work might include:

* Integrating the practical work materials with the relevant theory notes. This may still require cross-referencing where several learning outcomes and assessment objectives are targeted.
* Keeping a separate practical book enables records of all the practical investigations to be kept in one place. Learners need to learn how to manage practical files effectively, particularly in keeping the contexts and cross referencing to the theory. Care should be taken to develop and maintain these skills so that learners don’t perceive practical as something different from theory.
* An intermediate between these two extremes is having a separate section for practical investigations in each learner’s file with each syllabus section and cross referenced to the relevant theory.

**Organising a practical activity**

Preparing for practical work needs thought and organisation. The practical work may be an activity that forms part of a lesson, it may comprise an entire lesson, or it may be an investigation designed to last for several lessons. In every case, thorough preparation is essential to success.

Practical and investigative work should be integrated into the programme of study. Your lesson planning should identify appropriate practical investigative experiences for use at the most suitable time.

Considerations for integrating practical work within your programme of study might include:

* the resource implications in terms of equipment and materials in stock
* the seasonal availability of materials and the length of their shelf-life
* the time taken from order to delivery, potential for damage during despatch and cost of materials to be obtained from local, national or international suppliers
* careful scheduling for Centres with a large number of learners, such as arranging for several groups to do the work simultaneously or in quick succession, or changing the order of lessons for different groups so that scarce resources can be used effectively
* national or local health and safety regulations relating to chemicals, electricity, growing microorganisms etc., as well as regulations controlling use of controversial materials such as genetically modified organisms.

The next stage is to consider each practical activity or investigation. In an ideal course, you would go through each of these stages in developing each practical exercise in the course, but this is not always realistically possible especially the first time through a course. Obviously, all practical work should be subject to careful and rigorous risk assessment.

Additional considerations in designing a practical exercise might include:

* Decide on the aims of the work; the broad educational goals, in terms of the general skill areas involved (e.g. planning) and the key topic areas (e.g. animal transport systems or unfamiliar material).
* Consider the investigative skills being developed. Reference should be made to the syllabus. For instance, if the practical work is to be a planning exercise, which of the specific skills identified in the learning outcomes will be developed?
* With reference to the topics included, decide on the intended learning outcomes of the practical activity or investigation, again referring to the syllabus. For instance, which of the learning outcomes will be achieved?
* Assess any other context of the practical investigation. For instance, is it intended as part of the introduction of a concept, or to support a theory, or to demonstrate a process?
* Produce a provisional lesson plan, allocating approximate times to introduction, learner activities and summarising.
* Produce and trial a learner worksheet. Published procedures or those produced by other teachers can be used; alternatively produce your own. As a rule schedules produced by others need modifying to suit individual groups of learners or the equipment available. It is helpful to ask learners or another teacher to read worksheets before they are finalised as they can identify instructions that are ambiguous or use confusing or unknown terminology.
* Refine the lesson plan in relation to the number of learners for which the investigation is intended (whole class or a small group), the available equipment and materials.
* Carry out a detailed and careful risk assessment before any preparatory practical work is done, and certainly well before learners do any of the practical work.

Considerations in carrying out a risk assessment might include:

* + The likelihood that any foreseeable accident might occur. For example, learners putting a glass tube through bungs are quite likely to break the tube and push it through their hand.
  + The potential severity of the consequences of any such accident. For example, dropping a plastic dropper bottle of 0.01 mol dm-3 hydrochloric acid onto a desk will cause much less severe eye injuries than the same accident with a glass bottle containing 5.0 mol dm-3 hydrochloric acid.
  + Anything that can be taken to reduce the severity of the effect of any accident. For example, the teacher or technician preparing bungs with glass tubes before the lesson, or using eye protection such as safety spectacles during all practical work.
* Make an equipment and materials list.
  + materials and apparatus per learner or per group (e.g. chemicals, glassware)
  + shared equipment per laboratory (water baths, microscopes, pH meters)
  + any chemicals should include concentrations and quantities needed
  + any equipment should include number required
  + any hazard associated with specific chemicals or equipment should also be noted and cross referenced to the risk assessment.
  + the location of storage areas for equipment and chemicals may be cross referenced to this equipment and materials list
* Set up and maintain a filing system where master copies of the worksheets, lesson plans and equipment lists can be stored. It is helpful to have these organised, or at least indexed, by both their syllabus context and skills developed.
* Once an investigation has been used by a group of learners it should be evaluated in relation to intended outcomes and the lesson plan. It is important to obtain feedback from the learners about their perception of the work.

For example,

* + was the time allocation appropriate?
  + were the outcomes as expected?
  + did the learners enjoy the work?
  + did the learners understand the instructions?
  + was the point of the work clear to the learners?

If necessary the worksheet and lesson plan should be revised.

**Risk assessment**

All practical work should be carried out in accordance with the health and safety legislation of the country in which it is done. No activities should be attempted if they conflict with such legislation.

Hands-on practical work can be carried out safely in schools. If it is to be safe, then the hazards need to be identified and any risks from them reduced to insignificant levels by the adoption of suitable control measures. These risk assessments should be done for all the activities involved in running practical science classes including storage of materials, preparatory work by the teacher and by any technical support staff and the practical activities that are carried on in the classroom, whether demonstrations by the teacher or practical activities for the learners.

Risk assessment involves answering two basic questions:

1. **How likely is it that something will go wrong?** For example, learners using a double sided razor blade to cut up carrots are quite likely to cut themselves.
2. **How serious would it be if it did go wrong?** For example, the consequences of a spark from an experiment landing in an open bottle of magnesium powder are likely to be serious.

With the answers to these questions it is now possible to plan the practical activity to minimise the risk of an accident and to minimise how severe any accident might be. In our examples, this might include cutting up the carrot before giving to young learners, or providing older learners with an appropriate sharp knife. It might include bringing into the laboratory only the amount of magnesium powder required for the activity.

How likely it is that something will go wrong depends on who is doing it and what sort of training and experience they have had. For example, you would obviously not ask 11-year-old learners to heat concentrated sulfuric acid with sodium bromide, or to transfer *Bacillus subtilis* cultures from one Petri dish to another, because their inexperience and lack of practical skills makes a serious accident all too likely. By the time they reach post-16, they should have acquired the skills and maturity to carry such activities out safely.

Decisions need to be made as to whether an activity should be a teacher demonstration only, or could be done by learners of various ages. This means that some experiments should normally only be done as a teacher demonstration or by older learners. Perhaps with well-motivated and able learners it might be done earlier, but any deviation from the model risk assessment needs discussion and a written justification beforehand.

Occasionally, eye protection is thought of as the main control measure to prevent injury. In fact, personal protective equipment, such as goggles or safety spectacles, is meant to protect from the unexpected. If you expect a problem, more stringent controls are needed. A range of control measures may be adopted, the following being the most common.

Use:

* a less hazardous (substitute) chemical
* as small a quantity as possible
* as low a concentration as possible
* a fume cupboard
* safety screens (more than one is usually needed, to protect both teacher and learners).

The importance of lower concentrations is not always appreciated. The hazard classification of common solutions should be checked against hazard data sheets.

**Material Safety Data Sheets (MSDS)**

Your risk analysis should consider the hazards associated with the materials you propose to use. These risks are best assessed by reference to MSDS’s appropriate to the chemical(s) in use. These are generally supplied by the chemical manufacturer and supplied with the chemical. If this is not the case then there are many internet sites that have this information freely available. These sheets also provide useful information on the actions to take following an accident, including first aid measures, and should therefore be considered essential for all practical experiments involving chemicals, as part of the risk assessment process.

**Hazard key**

The following key applies.

|  |  |
| --- | --- |
| **C = Corrosive substance** | **F = Flammable substance** |
| **H = Harmful or irritating substance** | **O = Oxidising substance** |
| **T = Toxic substance** | **N = Harmful to environment** |
| **B = Biohazard** |  |

**Eye protection**

Learners will need to wear eye protection. Chemical splash goggles give the best protection but learners are often reluctant to wear goggles and are difficult to wear with glasses. Safety spectacles give less protection, but may be adequate if nothing which is classed as corrosive or toxic is being used.

Your risk assessment shouldn’t be restricted just to the materials, procedures and equipment being used, but should have a wider remit, covering the time from when the class enter the room until they leave it.

There are a number of publications which you may find useful in the safe planning of practical activities, such as:

*Safeguards in the School Laboratory,* ASE [www.ase.org.uk](http://www.ase.org.uk)

*Topics in Safety*, ASE, [www.ase.org.uk](http://www.ase.org.uk)

*Hazcards,* CLEAPSS,(available to members only) [www.cleapss.org.uk](http://www.cleapss.org.uk)

*Laboratory Handbook*, CLEAPSS (available to members only) [www.cleapss.org.uk](http://www.cleapss.org.uk)

*Hazardous Chemicals Manual,* SSERC, [www.sserc.org.uk/index.php/health-a-safety](http://www.sserc.org.uk/index.php/health-a-safety)

*Risk assessment in the chemistry laboratory*, Royal Society of Chemistry, <http://www.rsc.org/learn-chemistry/resource/res00001314/risk-assessment?cmpid=CMP00002777>