The Association for Science Education
Promoting Excellence in Science Teaching and Learning
ASE Health and Safety Group

Topic 2: Teaching health and safety through science

This topic (dated may 2013) is an updated version, with significant changes, of Topic 2, which appeared in the 3rd edition of Topics in Safety (ASE 2001).

2.1 Introduction

Experimental and investigative work has been an integral element in the teaching of science in schools for many years. Although students have always been taught to work safely, there is now a more-general requirement that they will be taught about health and safety and how it should be implemented. That is, they must understand something of the principles of health and safety, which is more than learning how to follow a set of safe working instructions.

The general requirement for students to learn about health and safety applies across the curriculum, not just in science. Curriculum areas such as design and technology, including food technology, and PE, spring readily to mind, but statistics, as taught through mathematics and other subjects, also plays an important part in understanding risk. However, teaching and learning science offers many opportunities for students to learn about health and safety in a 'live' practical situation which can provide them with insights into health and safety in general.

Some more-advanced and vocational science courses require quite detailed teaching of health and safety practice and regulation. Although such details are included in the specifications, it is often the case that the assessment of the health &safety elements is vague and cursory.

Emphasising health and safety at work is a good idea, despite how it is frequently portrayed, and undermined in the media. The alternative is, of course, quite unthinkable. The requirement for health and safety in the laboratory or classroom is sometimes misconstrued as an obstacle to developing practical approaches to science in schools and colleges. However, recognising hazards, assessing risk and working safely are important skills not only in the school laboratory but also at home and at work. They contribute to the general health & safety education of the school population. No less importantly, such skills also allow students to safely carry out the kind of experimental and investigative science that they often enjoy.

2.2 Hazards and risks

A **hazard** is any substance or equipment with the potential to cause harm. A **risk** is the likelihood of harm arising from the storage and/or use of that substance or equipment, also taking into account the severity of that harm.

Students need to be shown how to identify hazards from hazard labels, printed instructions, or their own experience. Students also need to be taught how to judge the nature of the actual risks to which they might be exposed. They should be taught that it is impossible to eliminate all risks, and that a judgement should be made about what level of risk is acceptable. For instance, playing rugby is a risky activity, in which injury, major and minor, is common. For rugby players the risks of injury are generally acceptable, are kept as low as possible by the controlled conduct of play, but they cannot ever be eliminated altogether.

To understand hazards and risks in school science, the students must also be taught some science. Without this, they will only ever be following instructions, which they could not apply to future, similar situations, whether in school or outside.

2.3 How to go about teaching health & safety

The health & safety principles which students should learn include the following.

- How to recognise and identify hazards
- How to identify the possible risks from those hazards
- What actions are needed to reduce those risks to an acceptable level
- What might constitute an acceptable level of risk
- How to put the required actions in to practice
- How to assess risk and formulate appropriate actions before undertaking tasks

Learning these principles begins before students even get to school, and is developed and refined when at school and, indeed, afterwards. The younger the child, the more the adult has to protect her/him from encounters with hazards. However, this protection has to be carefully and steadily withdrawn for learning to take place.

The teaching and learning of these principles takes place in a range of situations including the home, the primary school, clubs, on holidays, etc. The science teacher has to find ways to draw out and build on previous learning without clear knowledge of what such learning might have entailed. This will involve effective questioning and the imagination to make suggestions to students who may themselves not fully recognise what they have, in fact, already learned. This takes time, which must be planned for and built into the curriculum.

2.4 Opportunities in science teaching

A way of planning for opportunities to teach children about health and safety could involve identifying the hazards which might be encountered and have to be controlled during a topic or a school year. Such hazards may involve those associated with:

- handling and using unusual equipment ,which may be sharp, heavy, bulky or just awkward to handle, and may also be relatively fragile
- forces – pushes pulls, the effect of gravity and mass
- friction, and the lack of friction
- handling animals and plants, and growing plants
- working outdoors
- dissecting animals and animal parts
- growing microorganisms
- materials and chemicals provided by the teacher
- chemical reactions and the chemicals which are produced
- flames, heating, and handling hot things
- electricity, particularly at mains and higher voltages
- the Sun and UV radiation
- lasers and other very bright lights.
- radioactivity

A list like this can enable a department to readily identify the significant hazards which will be encountered in planned work. From this the department can identify those which offer the most appropriate and effective teaching opportunities for the age and experience of the students. Although this will take some time initially, the outcomes may remain broadly the same over several years.

Note that it's not necessary to take every opportunity to teach about health and safety, sometimes a quick reminder of the health and safety and what the students already know of it is sufficient. You are planning a science curriculum not simply a health and safety one. And remember that health and safety should be being taught across the curriculum, not just in science.

2.5 Putting it into practice

In school science teaching students about health and safety will involve the following.

1 Teachers, and technicians, leading by example and demonstrating consistent, health and safe practice. For example demonstrating:

- techniques the students are going to perform themselves such as simple distillation of e.g. ink, how to dissect a heart, or investigating stretching wires
- more traditional demonstrations such as the properties of radioactivity and the thermite reaction, or extinguishing safely a chip pan fire
- 'entertaining' demonstrations such as the whoosh bottle and the howling jelly baby
- and insisting that visitors (including senior staff and governors) also wear eye protection if appropriate.

2 Having secure ground rules for science work, which protect individual students and those around them and, of course, teachers, technicians and TAs. For example:

- using those given in the ASE publication *Safeguards in the school laboratory* (ASE 2006), the CLEAPSS model health and safety policy for science, or the SSERC model health and safety policy, all of which offer a good model.
- developing a set of rules through negotiation with the students would enable such rules to be better understood and would give students a sense of ownership

3 Students being taught both how to work safely and why the chosen practice is healthy and safe. For example:

- how, why and when to wear eye protection – perhaps put fresh eyes into concentrated sulfuric acid or sodium hydroxide to show the damage these cause
- how to handle hot objects including the Bunsen burner.

4 Students being allowed to practice healthy & safe working. For example:

- repeating a practical activity, once to learn healthy and safe technique, and then to obtain the scientific results.

5 Students learning to recognise that the way they work may compromise the health and safety of those around them, even if the individual him/herself perceives no personal risks are present. For example:

- when heating a liquid in a test tube, being careful where the open tube mouth is pointed
- taking off eye protection when other around are still doing practical work may be risky
- clearing up spilled, hazardous liquids which may splash or risk contaminating others, or make floors slippery.

6 Students being given opportunities to plan and justify (collectively and individually) safe ways of working. For example:

- students planning their own individual practical or field work; but teachers must still check that any plans a student makes do incorporate acceptable health & safety practice

–students being shown how to use appropriate H&S information such as on the CLEAPSS *Student Safety Sheets* which are available to all students on www.cleapss.org.uk. Also useful are some of the units from the ASE SATIS *World of science publications*. In Scotland students at Advanced Higher level are required to risk assess their projects and advice for teachers can be found in the SSERC document *Preparing COSHH risk Assessments for Project Work*, which is, at the time of writing, being updated.

7 Students being given opportunities to reflect on practice, which they may or may not have planned themselves, to review just how well health and safety was managed. For example:

–looking back over the steps needed to produce copper sulfate crystals from copper(II) carbonate.

8 For more advanced, often post-16 or BTEC students, they should be taught how to read and understand manufacturers' safety data sheets and other sources of hazard and risk information. For example:

–by providing manufacturer safety data sheets for the chemicals to be used in a forthcoming practical or project, and requiring the students to identify appropriate control measures/safety precautions (which must be checked by a teacher before any practical work begins).

It is important that students are *shown* how to work safely. A short demonstration is often the most effective way of teaching safe methods of working and of reducing the risk to students when they begin a practical activity. Safety during heating operations, for example, is dependent on correct technique that must be carefully demonstrated by the teacher. Table 1 lists measures for controlling the risk sin some common procedures carried out by year 7 (age 11-12) students.

In summary, teaching health and safety through science means:

- Effective, and enforced, rules and procedures for practical activities
- A planned programme to develop over time students' health & safety knowledge and understanding, in keeping with the science curriculum
- Clearly identified opportunities for teachers to explicitly teach about health and safety
- Occasional explicit demonstrations of healthy and safe working techniques
- Providing students with opportunities to discuss and practise healthy and safe working
- Providing opportunities for students to plan healthy and safe working in science (but teachers need to check before any practical work takes place)
- Taking opportunities to contextualise and exemplify practice in science lessons with situations students will encounter in other aspects of their lives.

Table 1: Controlling risks in some basic laboratory work carried out by Year 7 students

Activity	Hazard(s)	Risk of harm	Control measure(s)
Finding boiling point of water/ investigating changes of state	Beaker of boiling water on tripod and gauze	Scalding if beaker topples	Ensure gauze is flat; before beaker is heated, carefully clamp in position partially immersed thermometer; wear eye protection; ensure students stand to carry out experiment.
Measuring friction between load and lubricated surfaces	Oil, small polystyrene beads	Slipping on floor after spills of oil or beads	Work over a tray or similar container.
Measuring breaking strength of plastic bags	Falling masses	Injury from falling masses when breaking load is used	Ensure that drop height of masses is minimal or allow masses to fall into a suitable container.
Comparing the energy values of fuels	Flammable liquid (methylated spirits)	Burns from an uncontrolled combustion	Appropriate volume of fuel to be dispensed by teacher or technician away from flames; wear eye protection
Testing a leaf for starch	Flammable liquid (ethanol)	Burns from an uncontrolled combustion	Use electric kettle or extinguish Bunsen burners before ethanol is distributed by teacher or technician; wear eye protection
Solubility of copper sulfate	Copper sulfate (harmful)	Skin irritation from contact with crystals and; splashing solution into eyes	Avoid skin contact and wear eye protection; use stoppered tube when shaking up solution.
Simple apparatus for distillation of ink	Heated apparatus containing liquid (water based ink) at boiling point	Scalding if distillation vessel falls; cuts from broken glass	Clamp vessel being heated; wear eye protection
Chemical changes	Reaction mixture containing dilute acid and carbonate	Chemical burns from an acid spray	Use eye protection; ensure that quantity of carbonate added does not cause excessive frothing.

The following examples illustrate what this might mean in practice. Readers will probably identify others. Remember that the specific opportunities may well differ between schools, but the overall programme should provide the students with the skills, knowledge and understanding to recognise how and why health and safety is important.

Two examples

Using a Bunsen burner

Very early in their time at secondary school, students are generally taught to use the Bunsen burner. This is an exciting time for youngsters who, until then may have had little legitimate contact with flames, which provides a significant dilemma. The students cannot wait to light their Bunsen burners (for whatever purpose) but using a Bunsen is not simple, there is much to understand. Before any teaching the teacher must be certain s/he knows and understands how the Bunsen works. Once this is clear a teaching strategy might involve the following steps.

- The teacher demonstrates the use of the Bunsen, pointing out that the flame can be controlled in two separate ways (size and oxygenation), that the barrel of the Bunsen does not become hot but that the flame is hotter than the students will have experienced if they used candles in primary science, how to turn the gas on and off, and how to connect and disconnect the Bunsen tube.
- Allow a selection of students to join in the demonstration, to connect and disconnect the Bunsen, to control its flame and perhaps to experience and describe just how far above the flame it is possible to place a hand without experiencing discomfort.
- Demonstrate that a wooden splint laid across the chimney of a lit Bunsen blackens at the edges but not in the middle.
- Hold an old white tile, or similar, above a yellow (luminous) and a blue (roaring) flame to show how the luminous flame leaves a sooty deposit because of incomplete burning.
- Allow the students to handle Bunsens, to become familiar with their structure but not yet to use them.
- All of this might well take a full lesson with no 'science' apparently being taught. However, the teaching objective is to enable the children to learn something of a Bunsen so they can subsequently handle it safely. This involves developing some knowledge and understanding of the Bunsen and why there are rules and procedures for its use.
- The next lesson, could begin with one or two students revisiting and demonstrating the main features of using the Bunsen from the previous lesson, before the whole class is allowed to attach and light their own Bunsens (in pairs?), and use them to heat something simple.
- None of the above need involve any written work but if done well, will ensure that from then on, the students will be able to handle their Bunsens with confidence, needing only occasional reminders of safe practice.

The Sun, including UV and infra-red radiations

Children are taught that all life depends on the Sun. We benefit from exposure to it by producing vitamin D. We rely on it for our eyesight when we are out of doors during the day. The use of light to produce electricity is an important topic for study. But sunlight poses serious hazards to human health if exposure is prolonged or intense. Although children are now more regularly protected from the risks of over-exposure, it is important that they are taught the reasons why taking precautions is necessary. Sequencing such teaching depends very much on when topics such as light and photosynthesis are taught, and also when fieldwork is undertaken since this is where precautionary practice is likely to be required. Teaching points include the following.

- Not all the radiation from the Sun is visible. Sun 'light' also contains infra-red (IR) and ultra-violet (UV) radiations which are damaging and require us to take suitable precautions. The infra-red component of sunlight warms the body but it is the ultra-violet radiation that causes sunburn. The skin becomes red and painful to the touch - a warning to take action.
- UV radiation absorbed by the skin damages DNA directly but, with moderate exposure, this damage is repaired and initiates the production of a brown pigment - melanin. Melanin absorbs the energy of UV radiation and dissipates it as harmless heat, thus protecting the skin from further damage by small amounts of UV. Over time, and with continued exposure to sunlight, the skin becomes increasingly tanned. However, if exposure to UV is intense and prolonged, even very tanned skin can become sunburnt.
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- Damage to DNA by UV absorption in the skin can also be indirect. The UV radiation triggers chemical reactions which produce highly-reactive molecules such as free radicals and oxygen ions. These can diffuse through skin cells and react with DNA, even in areas not exposed to sunlight. The consequence of such DNA damage can be serious, leading to the development of various types of skin cancer including malignant melanoma. UV radiation also damages collagen fibres and therefore accelerates skin aging.
- It is clearly beneficial to limit direct exposure to UV radiation. Sun-bathing should be avoided completely or sessions kept to a minimum and only of a short duration. The head and skin should be kept covered by suitable clothing when outdoors in the sunlight. The application to the skin of sunscreen lotions may also be helpful. Their active ingredients absorb some of the UV radiation, thus limiting the effects on the skin. However, to be effective, the sunscreen must have a high sun protection factor (SPF) and be reapplied to the skin at very frequent intervals.
- Our eyes are also prone to damage by sunlight. UV radiation can cause a painful irritation called photokeratitis. With prolonged exposure, the conjunctiva, cornea and iris suffer from a form of sunburn. In normal sunlit conditions, this is unlikely but people on skiing or tropical beach holidays, or on mountaineering expeditions, have been affected. UV radiation, reflected from the surface of brightly-lit snow or sand, is absorbed and symptoms develop within an hour or so. Mountaineers are at greater risk because, at higher altitudes, less UV is filtered out from sunlight in passing through the thinner atmosphere. (Similar problems may afflict welders and even stamp collectors. UV radiation is produced by welding equipment and philatelists use UV lamps to reveal the phosphor bands on stamps.)
- Injury is, of course, prevented by wearing eye protection that blocks most of the UV radiation. Welders would be stupid not to wear goggles with the proper filters or a welder's helmet, and smart skiers just don’t travel without their snow goggles. But many sunglasses are low rated for UV protection and/or allow light to reach the eye from the sides.
- Looking directly at the Sun, even for a short time, is also most hazardous. In this case it is the thermal action of infra-red radiation that damages the retina and adjacent choroid. No symptoms are perceived until the tissues at the back of the eye have been destroyed, causing permanent blindness. Such disastrous injuries have occurred while watching a solar eclipse without sufficient and suitable eye protection, designed for this single purpose.