CLEAPSS

G14 Designing and Planning Laboratories

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CLEAPSS
Brunel Science Park
Kingston Lane
Uxbridge
UB8 3PQ
Tel: 01895 251496
Fax: 01895 814372
E-mail: science@cleapss.org.uk
Web Site: www.cleapss.org.uk

G14 Designing and Planning Laboratories

1. Designing for science

1.1 Introduction

This guide is written to help those planning and designing laboratories in schools, whether it's a whole new science suite or a refurbishment of an individual lab or prep room. The guide will be useful to science teachers, headteachers, education authority science advisers and inspectors, architects and property services departments. For the most part, we have assumed that readers will not be very familiar with designing laboratories and have tried to point out the pitfalls.

School science laboratories are an expensive investment and are expected to last for many years. A poor design will impact on generations of pupils, teachers and technicians. As is so often the case, the cheapest option is not necessarily the best value for money even in the short and medium term. A well-designed and fitted laboratory may have much lower maintenance costs. In its publication on asset management planning (for details see appendix 1) the government emphasised the importance of lifetime costs, balancing capital expenditure against running costs. Some modern designs have not proved to be sufficiently robust for school use and, frankly, look tatty after just a few years.

Most science teachers, and even architects, do not have much opportunity to practice at designing for science. Both may be tempted to draw upon personal experiences to identify what liked most / least about laboratories they have worked in. It is important, therefore, to use guides like this and other documents listed in appendix 1 to achieve an overview of the range of designs, what is possible and what to avoid. Where they exist, science advisers / inspectors usually do have good opportunities to visit a wide range of laboratories and see them in action. If necessary, it may be worth paying for their advice.

It might be useful to visit schools that have recently had new science facilities, not only to see the design but also to talk to staff about how the results work in practice. With this in mind, in 2007 the DCSF commissioned a set of designs under the title *Project Faraday*. In this project six brand new school buildings had special attention paid to their science facilities and a further 6 existing school buildings had designs for refurbishments. These designs and some accompanying information have been published by the DCSF as *Project Faraday. Exemplar designs for* science (see appendix 1).

Building Schools for the Future (BSF) is a government project that is aiming to "rebuild or renew nearly every secondary school in England". This guide has been reviewed and updated so as to be available for the many science departments that will be undertaking a rebuild or renewal.

CLEAPSS is in a unique position to have an overview of successful and unsuccessful lab designs. We visit a wide variety of schools each year and take around 7000 ***Helpline*** calls a year, of which about 3% relate directly to laboratory design and fittings. Many come from teachers or technicians, but others include science advisers and architects. Our experiences are summarised in this guide.

1.2 The people and processes involved

A very early consideration must be to identify the groups and individuals that may have a view on the design of new science facilities. Thereafter there must be a planned process by which each can be consulted at appropriate times during the design, and build, process. A planning calendar like the one on the next page will be useful to help effective consultation.

Planning calendar		
Event / action	**Predicted date**	**Personnel involved**
Map out the broad outline of the project including roughly when you want the work to happen and what temporary arrangements might be needed.		
Identify the available budget.		
Verify roughly what can be afforded.		
Identify essential and desirable elements of the work.		
Draw up broad plans for consideration and review.		
Draw up detailed plans.		
Check costs of large elements such as furniture, fume cupboards etc and or invite tenders. Revisit essential and desirable and what is possible.		
Agree contractors and suppliers, and verify delivery and build dates.		
Prepare temporary arrangements and contingency plans.		
Plan arrangements for supervision of the work and liaison with contractors.		
Plan the management of moving in and snagging.		
On-site.		
Commissioning, hand-over and moving in.		
Snagging.		

Individuals and groups who should be involved include:

- The science teachers and technicians
- The headteacher
- School governors
- School pupils and students
- The school buildings manager
- The school finance manager
- The architect
- The builder
- The local authority adviser for science and health and safety

It is important to talk to the users of laboratories – teachers, technicians and, perhaps, students. It is also important to avoid any one individual, even the science leader, having things all her/his own way. Highly innovative ideas (or very traditional ones, for that matter) will have a long working life and it can be very difficult working in idiosyncratically-designed accommodation.

1.3 The number and type of laboratories required

Above all, a science department needs laboratories. Unless the curriculum is to be unduly constrained, all science lessons need to be timetabled in laboratories. Various formulae have been suggested over the years for the number of laboratories but we believe the following is the most straightforward way of working out what is required.

Calculate the total number of periods of science taught per week now (or in the future, if this is likely to change). Divide by the number of teaching periods per week. This gives the minimum number of laboratories needed. Multiply by 1.11 to 1.25 to allow for the fact that laboratories should normally be used for only 80 to 90% of the week, to permit servicing and to allow sensible time-tabling. Rounding to the nearest whole number will give the number of laboratories needed.

$$\frac{[\text{Total number of science periods taught per week}] \times [1.11 \text{ to } 1.25]}{\text{Total number of periods in the week}} = \text{Number of labs needed}$$

For example, suppose, in a particular school, that 7 staff each teach 20 periods in a 25-period week. In addition, the head of department teaches 16 periods, a deputy head 4 periods and a member of the PE department teaches 6 periods. Thus there are 166 periods of science in the week. The calculation: 166/25 suggests a provision of 6.64 laboratories. However, to allow for sensible timetabling, 8 labs will be needed. The occupancy of 8 labs would be 166 / (8×25) i.e. 83% of the week. Theoretically the school could go for 7 labs but this would mean an occupancy rate of 166 / (7×25) i.e. 95%, which, experience has shown is simply impossible to manage in terms of servicing, cleaning and timetabling.

Rather than design labs specifically for biology, physics and chemistry, or lower-school and post-16 students, multipurpose labs offer much greater flexibility. However, it is likely that only some of the laboratories will have fume cupboards and these will inevitably be used for chemistry. A laboratory with more than one fume cupboard will be needed for post-16 chemistry but it should be large enough to be used for younger classes as well. Similarly, a laboratory with good blackout (as opposed to dim out for videos, etc) may be needed for post-16 physics, but it too should be suitable for other aged classes. New courses, such as the planned diploma, may require a mixture of different types of workspaces and this, too, is most easily catered for by a system that can offer flexibility.

1.4 Preparation and storage rooms

Detailed consideration of prep and storage rooms can be found in chapter 7. However, it is essential at the beginning of the planning process that the needs for preparation and storage are not overlooked. Irrespective of the final design, at the very least these rooms will be used to:

- prepare equipment / materials for lessons,
- wash up and dry equipment and dispose of materials after lessons,
- hold equipment / materials (often on trolleys) to go out to lessons and equipment/materials just returned,
- store chemicals safely and securely,
- store other equipment so it is accessible and secure,
- store radioactive materials safely and securely,
- allow technicians to undertake routine administration including managing teacher lesson requisitions,
- allow a certain amount of equipment repair.

These activities cannot be effectively and safely undertaken in rooms that are too small, badly laid out, poorly furnished, or located randomly around the science department. The work of technicians in supporting science lessons in integral to the success of those lessons and therefor the preparation ands storage needs must be considered right from the outset.

1.5 Other aspects of science department design

There are major advantages in having all the science accommodation on one floor, preferably the ground floor, with no steps or changes of level. Much equipment needs to be moved around and this should be easily possible using trolleys. If a department is not situated on the ground floor, a goods lift (hoist) may be necessary, although this is an expensive option.

Table 1 lists a range of rooms and facilities, in addition to teaching labs, which might be needed in a science department. For a discussion about layout of the whole department, see *Building Bulletin 80: Science Accommodation in Secondary Schools. A Design Guide* (see appendix 1). In addition, don't forget cleaners' cupboards, toilets, etc. The need for fire exits to the corridors may also impose constraints. The publication *Fire safety risk assessment, education premises* is also useful (see appendix 1). *Laboratory Design for Teaching and Learning* (ASE) (see appendix 1) allows you to plan the layout within a lab and offers options for choosing furniture etc.

Table 1 Accommodation, other than laboratories, required for a science suite

Preparation room	There are advantages in having one large central preparation room, serving the entire department. See chapter 7.
Store room(s)	Some items can be stored in a sufficiently large preparation room, but a separate, lockable, ventilated, chemical store is highly desirable, preferably opening off the preparation room. Store rooms for other items are useful to prevent clutter in the preparation room.
Science department office or departmental base	With the growth in paper work, e.g. schemes of work, assessment records, etc a departmental office is essential. The preparation room is a technicians' work area. It should not be used as a science department office.
Dark room / optics room	Now not generally considered necessary in schools, although if not provided, one laboratory will require reasonable blackout for post-16 optics work. Most laboratories need dim out for viewing whiteboards or screens, etc.
Animal room	Live animals will be needed from time to time, e.g. for observation and measurement. However, these can usually be kept in the teaching laboratory or preparation room. The cost of an animal room is rarely justified.
Greenhouse	Live plants are often required and a greenhouse can repay its cost many times over, if it is unlikely to be subject to vandalism.
Outside growing area and/or pond	The science department can make very effective use of outside growing areas, environmental areas, ponds, etc both as a source of specimens for work in the laboratories and for ecological investigations. Vandalism can be a problem unless the site is carefully chosen and/or the local community involved in its creation. Further guidance on this is available in CLEAPSS guide L221 *Developing and Using Environmental Areas in School Grounds* (see appendix 1).
Student resource base and other study areas	Science departments can promote independent study by the provision of a resource area that has a number of computers and paper resources. Unlike laboratories, pupils may be able to work there unsupervised. Imaginative designs can provide small areas where individuals or small groups can work together, on their own or with a teacher. In addition a department can provide other rooms more suited to discussion and debate, lectures or paper-based activities without taking up lab space. Experience of timetabling constraints suggest that such provision should not automatically be considered as a low cost alternative to one or more laboratories, but as additional facilities to the standard lab provision. This will produce a science suite that enables and promotes a wide range of teaching and learning approaches without constraining practical, lab-based science.

1.6 A planning checklist

It's not always easy to keep track of the design process to make sure that nothing important is omitted. The checklist below has been kept simple and straightforward, gives a useful overview, and will provide a science department with facilities that will allow its teaching to flourish.

General	Have you considered and planned for:	
1	Sufficient laboratories to teach practical science and allow time for proper routine servicing.	
2	A large enough prep room for the technicians to work, and to house immediately needed chemicals and equipment.	
3	Sufficient other secure and accessible storage including an internal (i.e. within the building) chemical store.	
4	Laboratories and prep room on the same floor and at the same level.	
5	A science staff room, equipped with tea and coffee-making facilities, for preparation, marking and meetings.	
6	Mechanical ventilation for the laboratories, prep rooms and chemical storage rooms.	
7	Protection from solar gain for windows that face the sun.	
8	Heat-sensitive, not smoke-sensitive fire alarms used in the science suite and corridor.	
9	Sufficient fume cupboards to teach chemistry.	
10	Sufficient black out to teach physics.	

Laboratories	Have you considered and planned for laboratories which have: (See also chapters 3 & 4.)	
11	A floor area of least $90m^2$.	
12	A bench space of 0.36 m^2 for each pupil to work on.	
13	Sufficient, well distributed, sinks, gas taps, power points and ICT connections for effective science teaching.	
14	A large sink with a hot water supply.	
15	An eye-wash station.	
16	Accessible shut-offs for gas, electricity and water and an earth-leakage circuit breaker on the electrical supply.	
17	Provision for pupils to hang coats and store bags.	
18	Space to park a trolley holding equipment and materials for the lesson.	
19	Windows that can be easily opened when required.	
20	Sufficient lighting with provision for lights close to the whiteboard to be switched off or dimmed.	
21	Lockable cupboards for storing materials and books.	
22	Provision for teacher-led demonstrations that might require gas, water and electricity.	
23	An interactive whiteboard, projector etc and enough space to connect the computer to data-logging equipment for demonstrating to a class.	
24	Sufficient display boards.	
25	A site for two small carbon dioxide fire extinguishers and a fire blanket.	

Laboratory furniture	Will the furniture have: (See also chapters 4, 5 & 6.)	
26	Laboratory bench height of 900 mm.	
27	Bench tops made of a suitable material, such as wood, stone-filled resin or solid laminate.	
28	Cupboards doors fitted with 270° hinges.	
29	Sufficient comfortable stools.	
30	Water taps of a non-rotating pillar design.	

The prep and storage room(s)	Have you considered and planned for preparation and storage facilities that have: (See also chapter 7.)	
31	Sufficient room for the technicians to prepare lessons without general interruption from other staff.	
32	An office area equipped with a computer and connected to the web.	
33	Provision for storage of technicians' reference books and other paper resources.	
34	If appropriate, provision for the storage of paper resources for teaching e.g. worksheets, etc.	
35	Provision for orderly storage of science equipment and materials, including 'bench' solutions.	
36	Sufficient space for trolleys.	
37	Workbenches set at a height of 900 mm and with enough working surfaces to meet the needs of the department.	
38	At least one large sink with a double drainer and hot and cold water supply.	
39	A lockable, ventilated chemical store.	
40	Provision for the lockable storage of highly flammable chemicals.	
41	Provision for the lockable storage for radioactive materials (should not be in the chemical store).	
42	Provision for the secure storage of gas cylinders, not in the same room as the flammables cupboard or the radioactive materials.	
43	A ducted fume cupboard, or easy access to one.	
44	A refrigerator, freezer, and dishwasher or laboratory glass washer.	
45	Display and message boards on the wall.	
46	A site for two small carbon dioxide fire extinguishers and a fire blanket.	

1.7 Building in progress

Constructing a completely new science block can go ahead at any time without disturbing teaching. However, conversion or upgrading existing accommodation may well be noisy, dirty, dangerous and generally disruptive. Most schools, therefore, attempt to arrange such work for the summer break, which becomes a peak period for suppliers and manufacturers. Problems can arise with long delivery times, staff shortages and sub-contracted fitters. In addition, school staff who need to be consulted or who could spot difficulties as they arise, may well be on leave. Delays are commonplace.

It is therefore better if schools can arrange for work to be done at other times of year, possibly by making use of temporary accommodation. Alternatively, could rooms be released when the examination season starts or the work done during the Easter break? Whenever the work is arranged, it is wise to assume that it will not be completed on time, and make contingency plans.

Watch what is going on

Someone in the science departments should obtain copies of any plans as and when they are drawn up or modified. This can be useful to help ensure that all changes, even last-minute ones, are considered by, and agreed with, the department. Plans can also help resolve disputes when building starts.

Once contractors begin work it remains vital that science staff keep a close eye on what is happening. Many small decisions are made on site and it is important to identify potential mistakes and inform the architect or project manager before it is too late or too expensive to rectify them. If building work is to be carried out in the holidays try to arrange a rota so that senior science staff come in regularly and frequently to check what is happening. For local authority schools, the property services department may be contracted to oversee the project. For large projects, this is usually worthwhile since science teachers are not trained site managers.

Some suppliers use their own fitters which means that the fitters build up experience of working with the products you are interested in. Others make extensive use of subcontractors, often for individual parts of the project, which may be less satisfactory. For example, electricians are specialists who often come in to do a particular task, without necessarily understanding the nature of the whole project. In one school, wall-mounted sockets were installed too low so that when the benches were fitted, moulded plugs could not be inserted. Details of heights for sockets and the position of any cut-off switches are often not specified in drawings and may be decided on the day of fitting by whoever is doing the job. Where the location of such installed items is important, it is best to write information clearly on the walls. Fitters installing gas or water taps sometimes find it is quicker to drill one large hole, rather than several smaller ones, making anti-rotation devices useless. This emphasises the need for a clear brief and instructions.

Temporary arrangements

The *Construction (Design and Management) Regulations* 2007 (CDM) (see appendix 1) place various health and safety responsibilities on the designer, the contractors, and on the client (i.e. the school or local authority). The Regulations do not apply to small projects where the project will last for less than 30 days, but new building, and some refurbishment of laboratories, will be covered.

If the Regulations do apply, then the HSE must be informed and a CDM co-ordinator appointed. One of the duties of the CDM co-ordinator is to prepare a health and safety file. The Head of Science, science advisor, etc, will have specialist knowledge that they should draw to the attention of the CDM co-ordinator. For example, during a refurbishment, it may well be necessary to remove chemicals into temporary storage. The nature of the chemicals, their hazards and any particular storage requirements may need to be pointed out. CLEAPSS will be happy to discuss with members the risk assessment involved in the use of temporary storage.

Dealing with and moving the radioactives cupboard is a particular instance where the department needs to make some arrangements of its own. Contractors have been known to 'lose' an entire radioactives cupboard and its contents, generally because the person on the ground has no idea what he is dealing with. For further advice on this see the CLEAPSS guide L93 *Managing ionising radiations and radioactive substances in schools.*

Moving in

There will normally be a hand-over date when the supplier says "We have finished – it is all yours". The contract terms and conditions will usually specify how minor problems ('snagging') will be dealt with. Science staff need to be careful to compile a list of problems and ensure they are rectified before hand-over, or obtain an agreement that they will be rectified afterwards. Fume cupboards should be commissioned, i.e. they should be tested and shown to comply with the relevant specification, and the supplier should provide the school with the written result of these tests. Other items may also need to be commissioned, e.g. electronic gas and water shut off systems. The service manual giving details of how various items of equipment are to be used should be available at the hand over.

If a new suite of laboratories has been built, there will be lots of equipment and chemicals to be moved in. There is often an unwritten assumption that technicians will do this. There may be advantages in such an arrangement in that technicians will know the hazards of chemicals, understand that a Fortin barometer must be carried upright, etc. However, before making this assumption make certain that manual handling issues caused by moving large quantities, perhaps up stairs, or over large distances are resolved. Transporting bulk chemicals by road, if necessary, is a specialist task which is now beyond the scope of teachers or technicians. If the building work and hand-over is done during the holidays, who will be available and will technicians need to be paid overtime?

1.8 On-going maintenance and repair

All laboratories, including those that are brand new, need maintenance and repair. Try to make sure that the service manual specifies the manufacturer and details for various fittings – water and gas taps, etc. Then, if these need to be replaced, new items can match the existing fittings. Indeed, it is a good idea to obtain a stock of spares, certainly the ferrules from the bottom of stools and detachable tap nozzles, but perhaps even one or two gas and water taps.

For repair work schools often use local contractors who may lack experience or not know the suppliers of original fittings. It is important, therefore, to specify exactly what is needed, i.e. like-for-like replacement, and, if necessary, CLEAPSS may be able to suggest sources. Do not accept non-matching gas taps, especially if they have a different size nozzle. For repairing gas fittings, a *Gas Safe*-registered contractor must be used. Similarly, with water fittings, most plumbers will not know where to obtain laboratory taps, and may try to install domestic-style fittings.

Bench surfaces will need maintenance from time to time to keep them in good condition (see section 8 of the CLEAPSS *Laboratory Handbook*). Bottle traps will need to be emptied on a regular basis and plans made to ensure that this happens.

2. Planning and designing a laboratory

2.1 General principles

For even one new laboratory there are a number of important points to consider:

- How big can it be? This will determine how many pupils can be sensibly taught in the room and what range of teaching and learning approaches might be possible. (In Northern Ireland, there is a legal maximum class size, but in England and Wales there is no limit. Anyone in Northern Ireland planning new science accommodation must consult the *Department of Education Building Handbook*; section 4 (see Appendix 1). There are some significant differences in regulation and practice in the Province from other parts of the UK). There is more detailed discussion of room size later in this chapter but it is always a good idea to make the useable space as large as you can. Future changes are more easily accommodated in a larger room than a smaller one.
- What room layout do you want? Chapter 4 has more on this but layout can be constrained by what services you want, and where.
- What image of science do you wish to present. This may influence your choice not only of layout but of bench surfaces and furniture colours. Chapters 4 & 5 have more on this.
- How much can you spend? Use your money wisely by contacting several suppliers/manufacturers to obtain their latest catalogues. Ask them for names of reasonably local schools where they have installed labs and visit them if you can.
- Who will draw up the plans? Ask building professionals to draw up detailed plans and specifications; obtain several quotations for the work.
- What are your contingency plans? Be prepared to prune plans drastically if costs overrun your available budget.

Rules of thumb

- Larger spaces offer much more flexibility than smaller.
- Fewer fixed structures also offer more future flexibility.
- Buying cheap furniture and fittings will probably turn out to be very expensive over a 25 year lifetime.

Compromise is usually necessary. A goods lift (hoist) is highly desirable if the science department is not on the ground floor, but may simply be beyond the budget. However, consider the consequences of not installing such a facility on the legal requirements of the *Manual Handling Regulations*. Implementing the Disability Discrimination Act may well involve the installation of a passenger lift. If located sufficiently close to the science department this may do away with the need for a separate science goods lift. The structure of the building may make it impractical to put fume cupboards where you want them and this may have knock-on effects on the rest of the laboratory. As budgets are likely to be tight, some items may have to be cut or downgraded at the last minute if something else proves unexpectedly expensive. It is important to design laboratories for a realistic number of pupils. A laboratory that is designed to cater for, say, 28 pupils, will struggle to cope with 33. Pupils will probably have to sit with their backs to the teacher, may not have adequate room for their knees when seated, may not have services in a convenient place and may be dangerously over-crowded for practical work.

2.2 Some details to consider

There is a need to balance capital expenditure against running costs. The concept of lifetime costs is particularly relevant in the context of school laboratory fume cupboards. The calculation in section 2.4 shows that the lifetime costs for ducted cupboards will be appreciably lower than for filter fume cupboards, despite the higher capital cost of the former.

There are major differences between refurbishing an existing laboratory and adapting non-science accommodation to laboratory use. For example, in most laboratories, gas, electricity, water and drainage services will be required on at least some benches. It is very expensive, noisy and dusty to dig up existing floors in order to lay ducting for such services. Drains present particular problems. In a new build, services can be easily placed wherever required, but a decision on the location will be needed at an early stage, when the foundations are laid and perhaps before the final layout has been agreed. In an adaptation of an existing laboratory, service ducts may well be available, but not necessarily at the ideal location. Almost certainly, they cannot be moved, although it may be possible to box them in. Where non-science accommodation is adapted, it may well be necessary to accept that only services around the periphery of the room are possible, perhaps supplemented by peninsular arrangements. (Note that in Northern Ireland, the DENI room layout and guidance specify the briefs for laboratories)

Some architects are very experienced in laboratory design but many are not. Architects may, in turn, call in other experts such as ventilation engineers but it would be unwise to assume, for example, that s/he is an expert in fume cupboards for school laboratories. Appendix 2 is a model brief for a laboratory which could be used to provide an architect or contractor with the basic features of a lab which you want. Members are free to copy and adapt it as necessary (a Word version is on the members' part of the CLEAPSS web site) but we would welcome feedback from users.

It is important when asking for quotations from contractors that you specify very precisely what you want. In general, furniture and equipment should comply with the relevant and current British Standard. BS3202 is the standard for laboratory furniture, but much of it is irrelevant to schools. The DfEE document *Furniture and Equipment in Schools: a purchasing guide*, (see appendix 1) gives some guidance although is not specifically aimed at science suites. The standard for fume cupboards in schools is given in Building Bulleting 88 (formerly known as *Design Note 29 Fume Cupboards in Schools*) (see appendix 1). The British Standard for fume cupboards, BS 7258, acknowledges that it may not be relevant in all circumstances and specifically mentions *Design Note 29 Fume Cupboards in Schools*.

Some firms specialise in laboratory work and are very knowledgeable; others are not. Find out whether the installation is being done by a firm's own staff or by subcontractors. An apparently cheap quotation may be cheap because a firm is giving you exactly what you asked for. A more expensive one, from an experienced laboratory installer, may be giving you what it knows from experience you are likely to want, if you had thought to specify it. For example, an experienced company will usually provide sufficiently thick bench materials to avoid the risk of cracking, and a drip groove will be carved on the underside of a bench. For ideas on what to specify, see Appendix 2. Reputable companies complain, with some justification, that they are undercut; the cheapest quotation is not necessarily the best. Always ask for the names of two or three local schools where the company you intend to use has installed the system of interest, two or three years ago; then visit and talk to the staff there.

2.3 Size and shape of the room

The size of the room needed is obviously related to the number of pupils to be taught there. For a fuller discussion, see the CLEAPSS leaflet PS9 *Science Class Sizes, Laboratory Sizes and Possible Effects on Safety.* In *Safety in Science Education* the (then) DfEE states:

> There are no regulations controlling the size of individual laboratories but adequate space is clearly needed for safe practical work. For 30 pupils at key stages 3 and 4, 85 m^2 is recommended; below 70 m^2 a laboratory will be appropriate for groups of 25 or fewer.
>
> As well as overall area, the area of work surface available for each pupil affects safety; 0.36 m^2 is recommended as a minimum.

For 30 pupils, modern purpose-built laboratories are likely to have an area of 85 to 95 m^2. In Northern Ireland, 90 m^2 is required for 20 pupils. In *Science Accommodation for Secondary Schools* the (then) DfEE suggests 83 to 99 m^2 is needed for a class of 30 pupils below age16, and 20 post-16 students. In the past 80 or 85 m^2 was quite common. This can give a satisfactory, although hardly generous, amount of space, especially as class sizes are rising, pupils are physically bigger than in the past and there is a need to accommodate large items such as computers. For those departments that prefer a degree of separation between practical and theory work larger labs are virtually essential. Older, general-purpose laboratories could well be 100 m^2. Older laboratories intended for 6^{th} form use could be as small as 50 m^2. In most schools it would be unwise to design such small laboratories now, as designating some accommodation specifically for A-level use is rarely a cost-effective use of limited accommodation and may create huge time-tabling problems.

Where new laboratories are created by conversion or adaptation, it is quite possible that the area will be below 80 m^2. This may seriously constrain the layouts that are possible and lead to over-crowding.

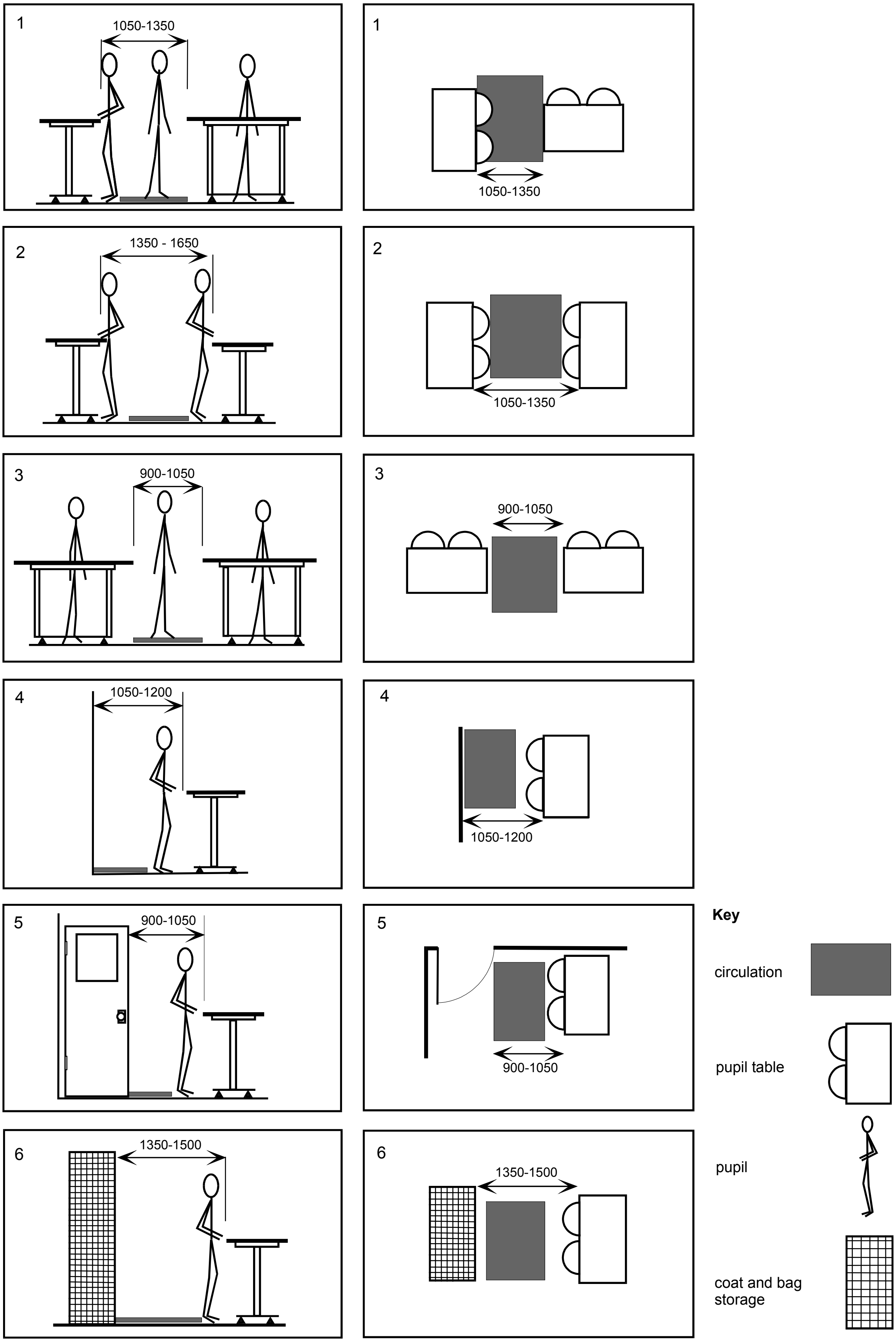
The shape of the room is also important. A long thin room gives poor acoustics and poor sight lines. Laboratories are larger than ordinary classrooms; they have hard reflecting surfaces (the benches) and sometimes noisy equipment (extractor fans, fume cupboards). This results in poor acoustics. Equally, it seems to be quite difficult to provide a satisfactory layout of benches in an almost square room. In a 90 m^2 laboratory, 10m $\times$ 9m works reasonably well. Whilst, traditionally, the teacher's base has been on the shorter wall, there may well be some advantages in having the room the other way round. It should at least be considered. Pupils will be closer to the teacher although some sight lines may be awkward. If windows are (mainly) along one long wall, the direction of the Sun should be considered, to avoid the teacher being dazzled when watching the class.

The size of the room is not the only factor – the amount of bench space per pupil is also important. The DCSF recommends a minimum of 0.30 m^2 per pupil, but 0.36 m^2 per pupil is a figure commonly used and this permits two pupils to sit at a standard table (1200 mm $\times$ 600 mm), with each having a 600 mm length of bench. Octagonal benches often have a front edge dimension of 745 mm and, even allowing for the taper, this can give more than 0.36 m^2 per pupil. However, sometimes smaller octagons are used, e.g. 600 mm (or even less) front edges, which obviously gives less space, especially if there is a raised portion in the middle. Remember the need for knee space when sitting at a bench. If, in large classes, pupils have to sit around the sides of the room, the positioning of cupboards may prevent them sitting comfortably when working.

A common problem is to leave too little space between workbench and cupboards, or between pupils who are working back to back. The diagram on the next page is reproduced, with permission, from *Science Accommodation for Secondary Schools* which itself was adapted from BS3202 and shows safe distances between benches, cupboards, etc.

Modern laboratories tend to have much lower ceilings than traditional ones. This means that there is a much smaller volume of air and hence any fumes are less diluted. As any fumes are likely to be warmer than the surrounding air, they will tend to rise, but with a low ceiling this means that they may end up at head height, rather than out of harm's way. Even if there are no fumes, the heat generated by a class set of Bunsen burners can make conditions very uncomfortable. Specify the greatest ceiling height that you can but additional ventilation may well be necessary (see section 3.6). Ventilation may affect the operation of fume cupboards. In Northern Ireland DENI specifies a minimum ceiling height of 2.7 m for new buildings.

Figure 1 Safe distances between benches, cupboards etc[1]



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1 Reproduced with permission from *Science Accommodation in Secondary Schools,* Building Bulletin 80, DfEE, The Stationery Office, 1999.

2.4 Fume cupboards

Fume cupboards are considered in detail in *Building Bulletin 88,* CLEAPSS *Guide* R9a and other publications. This chapter is only intended to give a brief overview. Fume cupboards may either have ducts, where fans remove hazardous fumes from the laboratory and discharge them to the atmosphere, or filters which remove fumes and recirculate the air to the laboratory. The latter are cheaper to buy but the running costs are much higher and, in the medium to long term, will normally be the more expensive option.

Fume cupboards are essential items to include in a suite of laboratories and preparation rooms. If science is taught to Key Stage 4, it is recommended that half of the laboratories should be fitted with fume cupboards. This provision could increase if years 12 and 13 are taught chemistry to A or AS level or GNVQ. There should also be a fume cupboard in the preparation room where hazardous bulk solutions and gases are handled by technicians. This will avoid them interrupting classes and transporting hazardous materials and equipment to and from laboratories.

The cost of a fume cupboard with ducting will be in excess of £3500 and it may be tempting to economise on the number required. However, to do so, could increase the likelihood of carrying out experimental work with hazardous gases and volatile chemicals in the open laboratory, increasing the risk. If fume cupboards are provided in less than a third of the laboratories, then those rooms with fume cupboards will be used mainly for chemistry, which may conflict with the desired teaching methods of the department. If fume cupboards are fixed, then room changes will be required when certain hazardous procedures are being carried out.

It is important that provision for fume cupboards is planned at an early stage. To function properly, ducts must rise to above roof level, which may be considered unsightly. Airflow may be seriously affected by draughts from doors, windows etc. Siting is discussed in detail in *Building Bulletin 88*.

If ducted cupboards are used they must be located so as to ensure maximum visibility by a class, not tucked into an obscure part of the room. If they are sited on a side wall (or even worse in a corner) it will be very difficult for 30 pupils to see any procedures in the fume cupboard as the demonstrator will be in the way. It is possible to obtain fume cupboards with a flexible duct. This allows the fume cupboard to be moved away from the wall so that the teacher can stand behind and the pupils can obtain a good all-round view of the operations that are being demonstrated. However, the flexible hose used for ducting may need periodic replacement and special connection points for gas, water and drainage may be required.

These problems appear to be avoided by using mobile filter fume cupboards. However, these have their disadvantages too. The filter will need to be tested regularly (more expensive and/or time-consuming than just testing the air flow, which all fume cupboards require), the filter will need replacing at regular intervals (a cost of over £200 to the departmental budget), the cabinets may be less robust and the fitting of service points increases costs and limits mobility to about 1 m from the service point. In addition, no filter is 100% efficient and residual smells may cause concern. Table 2 overleaf provides an estimate (at 2008 figures) of the lifetime costs of the two sorts of fume cupboards. In making this calculation we are confident that a ducted fume cupboard will last 25 years but we are less sure about a mobile, non-ducted fume cupboard. If the latter lasts only 15 years then the lifetime costs will rise accordingly.

Table 2 Comparative costs of fixed and recirculatory fume cupboards (2008)

Ducted fume cupboard		Recirculatory, filter fume cupboard	
Cost of purchase and instillation with all fittings.	£3600	Purchase	£2376
Cost of annual testing for 25 years	£1000	Cost of fitting at least one set of docking connections to supply gas and water	£500
		Cost of testing for 25 years	£2500
		Cost of 5 filters	£1100
		Cost of 10 pre-filters	£120
Total cost for 25 years	**£4600**		**£6596.00**

2.5 Coats and bags

Pupils often carry a number of books, folders, etc to lessons. Whether brought in plastic carrier bags, rucksacks or carried loose, they present a serious storage problem. Left on workbenches they are likely to be in the way and, if chemicals are being handled, may well be damaged. Placed on the floor, they present a serious trip hazard, as pupils move around to collect equipment, conduct their investigations, etc. A dozen open-fronted locker-type spaces are quite inadequate for a class of 30. Ideally, each pupil needs his/her own locker space and there should certainly be at least one between two, with spare capacity for those with large bags. In any case, putting all the bag storage in one location is likely to result in severe congestion at the start and end of lessons. Racks outside the laboratory can save space within it but, in most schools, these will not be sufficiently secure.

Increasingly, pupils also carry their outdoor coats with them to lessons. Placing them over chair backs, as in most other classes, is not feasible where stools are used. Draping them over stools is potentially dangerous and puts them at risk of damage by chemicals. One coat hook between two pupils is the very minimum that is required. To avoid congestion, two racks in separate parts of the laboratory are preferable to one rack. Hooks should be at a height where they will not poke out the eyes of younger pupils: about 1.2 m above floor level will probably be suitable in many schools. Some bags could be stored on a shelf above a row of coat hooks, thus giving some protection from the hooks.

3. The laboratory environment

3.1 Introduction

This chapter examines perhaps rather mundane facilities within the laboratory which, if not seriously considered, can cause major problems. Financial, security, health, safety, welfare and environmental issues all need to be addressed and compromises may have to be reached. The bare requirements are laid down in the *School Premises Regulations* but there are many Building Bulletins that provide good advice and guidance on various aspects of design.

3.2 Acoustics

The maximum acceptable, background noise level in a science laboratory is the same as in any other teaching room, i.e. about 40 dB. Should a laboratory be next to a road, measures may need to be taken to reduce noise levels but these could affect other important aspects such as ventilation. The recommended reverberation time for a laboratory is in the range 0.5 to 0.8 s. If reverberation time is any longer than this, when the teacher and pupils speak they tend to speak louder to make themselves heard which only makes the situation worse. Acoustic panels, window blinds and drapes and wooden furniture reduce reverberation time. It is unwise to fit acoustic panels on ceilings because this will not allow the teacher's voice to be reflected to all pupils. It is advisable that fume cupboards and other ventilation units run at less than 65 dB (at a distance of 300 mm) from the motor so that teachers can heard over the machine and not be tempted to switch it off if the fume cupboard motor is too loud. Guidance for designers can be found in *Acoustic Design of Schools: Building Bulletin 93.*

3.3 Heating

The *School Premises Regulations* require that the heating system should maintain a temperature of 18 °C, 0.5 m above floor level when the outside temperature is -1 °C. Laboratories should not need to be warmed up using Bunsen burners during the first period of the day. Interestingly, *Building Bulletin* 87 mentions that vertical gradients should be avoided and the temperature at 2 m should not exceed that at floor level by 3 °C. This could be quite difficult to avoid when 15 sets of Bunsen burners are operating in a room with a low ceiling.

Although we do not recommend outside chemical stores, if one has to be built, there should be some heating to prevent contents of bottles freezing and condensation dampening, and eventually rotting, labels.

For work involving microorganisms in which draughts must be prevented, the use of hot air blowers should be avoided unless these can be easily switched off in individual labs.

Heating systems need to be planned with furniture layouts in mind to ensure they work effectively.

3.4 Lighting

Guidance on lighting is given in *Building Bulletin 90.* Science rooms should be treated as any other room and should have an illuminance of not less than 300 lux on the work surface (350 lux in Northern Ireland). The section on science work and laboratories stresses a need for "adjustable bench lights where directional lighting is appropriate", i.e. portable lighting. Usually, special lighting for microscopes and physics activities would be provided using portable lamps. Particular attention should be paid to glare from white boards, projection screens and computer monitors and from benches with pale colours. Lighting over a demonstration area or projection screen should be separately switchable.

Some schools have installed time switches and other systems to control lighting on environmental grounds. Unless these can be reprogrammed or overridden then they can be a considerable nuisance to a teacher or technician working in the room.

3.5 Windows

Windows can be treated as a source of light or ventilation and provide a view out of a room. It is recommended that a minimum of 20% of an exterior wall is glazed (in Northern Ireland one wall should be glazed to bench height). However, if windows occupy too large an area or are south or west facing, the room may warm up to an unbearable temperature during a sunny day. Summer-time temperatures in excess of 28 °C are considered undesirable. Protection can be obtained by using outside shading (which will affect day lighting of the room) or blinds. Curtains may be considered for some laboratories but are unsuitable where Bunsen burners are used around the side bench.

It may be necessary to darken the room (dim out) when visual aids are used and to reduce glare. Black material is unsuitable as it absorbs too much heat and warms up the room. Grey reflective blinds are suitable. Blinds should not be allowed to flap freely because any wind will cause noise, possibly break the blind or knock over equipment. Full blackout may be required for certain activities during lessons on light in physics and occasionally in biology. Flexibility of use will be severely limited if this is available only in one laboratory.

The means to open windows and/or to operate blinds should be considered when the furniture layout is planned. Too often it is impossible to reach the mechanism safely because tables or benches are in the way. Climbing on bench tops or stools is not acceptable.

3.6 Ventilation

The *Education (School Premises) Regulatio*ns require that teaching rooms in schools should be ventilated at a minimum rate of 8 litres per second per person. For a teaching room with 31 people present this becomes 893 m^3 hr^{-1}. For a room with an area of 90 m^2 and a height of 3 m this becomes equivalent to 3.3 room air changes hr^{-1} (ACH). *Building Bulletin 101: Ventilation of School Buildings* discusses the issue in more depth and recommends the following.

Ventilation should be provided to limit the concentration of carbon dioxide in all teaching and learning spaces. When measured at seated head height, during the continuous period between the start and finish of teaching on any day, the average concentration of carbon dioxide should not exceed 1500 parts per million (PPM).

In addition to the requirement to meet the carbon dioxide performance standard, it is recommended that the design should also meet the following advisory performance standards that reflect the needs of the School Premises Regulations and the recommendations of the Health and Safety Executive.

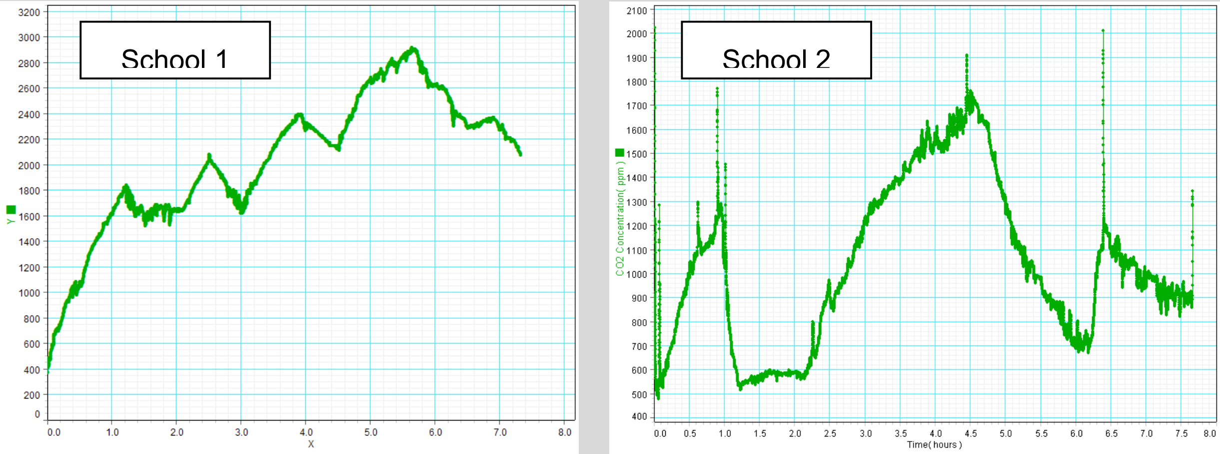
- The maximum concentration of carbon dioxide should not exceed 5000 PPM during the teaching day.
- At any occupied time, including teaching, the occupants should be able to lower the concentration of carbon dioxide to 1000 PPM.

Building Bulletin101 recommends (section 2.5) that a ventilation rate for the laboratory and prep rooms of 5 air changes per hour should be adequate to deal with additional carbon dioxide from Bunsen burners.

To provide adequate ventilation, windows should be open at the top to let warm air out and at the bottom to let cooler air in but remember that excessive draughts can affect Bunsen burner flames. Restricting whether, how and how far windows open, for reasons of energy conservation, noise control or to prevent intrusion, may limit ventilation. The lab may, therefore, require forced ventilation. If this becomes necessary, choose an acid / steam resistant extractor. It is important that the volume of the room is taken into consideration when choosing the right specification of the unit. It is more efficient, although more expensive, to have two smaller working units than one larger unit. It is also necessary to have a sufficient in-flow of air so that the extraction fan(s) work efficiently. This could be accomplished by leaving a door open but teachers often do not like doing this during lessons so suitable windows or vents are needed. Alternatively, one or more fans can be installed to blow fresh air in while other fans remove stale air.

Figure 2 Variation in carbon dioxide levels over a day in labs

Science departments may have a datalogging system with a carbon dioxide sensor that can be used to monitor the air in a room. CLEAPSS monitored a number of schools / labs using a *Pasco* datalogging system. School 1 had a laboratory that caused concern to teachers, quite possibly because of the high carbon dioxide levels. Levels of CO_2 increased throughout the day because even after a class had left there was little chance of getting the levels back to normal. School 2 had some mechanical ventilation so that when the children had left, fresh air was coming in. The peaks in both graphs occurred when the Bunsen burners were used for a short time. (The very tall spikes in school 2 occurred when a pupil approached close to the sensor.)



Schools that have reconditioned air circulating around the building have reported problems from teachers of other subjects who object to the aroma of organic chemicals being pumped into their rooms. CLEAPSS has even heard of schools switching these systems off because they are so expensive to run. Forced-air ventilation that is not under independent control could be highly undesirable for work in microbiology when draughts must be prevented.

Technicians deal with chemicals in bulk often in small rooms. Ventilation is no less important for the preparation room than the teaching laboratories.

3.7 Doors

Doors to labs, preparation and storage rooms must be lockable. Contrary to popular opinion, except in Northern Ireland, there is no requirement for a second exit door to a laboratory, unless the room exit is in a dangerous position. In its previous guidance, *Fire and the Design of Educational Buildings* (DES, 1988), the laboratory was classified as an “area of high fire risk” so that any door should have a fire resistance of not less than 30 minutes and Class 0 surface spread to wall and ceiling surfaces. If any part of a laboratory was more than 12 m from the door exit then another exit should be available. This guidance has now been withdrawn and the employer must now carry out a risk assessment before deciding on appropriate provision. In practice, in new buildings it is normal to provide two exits to laboratories.

Fire doors should be self-closing, remain closed whenever possible and, because they must have a close fit to the frame, they are often very difficult to open, especially by those carrying equipment or pushing trolleys. To avoid manual handling problems, doors can be fitted with electromechanical or electromagnetic devices that hold the door open until such time that the alarm system activates. Naturally, the doors would be shut when the school is unoccupied. It would be useful to check regularly with a spring balance the force required to open and hold fire doors apart.

Because of security problems, (i.e. the need to keep laboratories locked, and the hazards of substances used or stored) laboratories should not normally be a fire-escape route. It is sensible to insert glazed panels into doors to allow individuals to see who or what might be on the other side. Such panels should be long enough to allow for wheelchair users and short people. They must also meet the recommended standards in the *Workplace (Health, Safety and Welfare Regulations) 1992. Approved Code of Practice*, Regulation 14.

3.8 Floors

If any activities in a laboratory involve levelling, e.g. using an accurate balance, a sprung floor is too flexible and hence, unsuitable.

Vinyl

The most popular covering material is vinyl, which is resistant to most chemicals. Safety flooring contains aluminium oxide and quartz embedded in the polymer that gives the flooring superior non-slip but distinctly abrasive properties. It can be recognised by light reflecting from the embedded crystals. It is designed for areas that may become wet and is often thought to be suitable for school laboratories. There are no intermediate grades of slip resistance in moving from safety flooring to normal, smooth, vinyl flooring. However, safety flooring may be susceptible to indentation by stools. As its rough surface abrades a stool's rubber or plastic ferrules (end caps), the exposed metal edges of the stool's feet then cut and damage the floor further. It is worth looking at the indentation data provided by various manufacturers. The measurement procedure for this material is laid down by BS EN 433. School cleaners will need to know that slip-resistant flooring requires more than just mopping; mechanical agitation is essential to remove dirt from the tiny crevices.

A well-made, smooth, vinyl floor has more resistance to abuse by stools than safety flooring but will be more slippery when wet. It is less expensive than safety flooring. Very light-coloured floors show marks from the rubber soles of shoes and stool ferrules. These can, however, be removed by appropriate cleaning agents and an abrasive pad. Technicians have reported that it is also difficult to see the presence of water on pale-coloured floorings. Naturally, the best method of avoiding slips is to report and remove liquid spills once they occur and to wear sensible shoes.

An underlay should always be used beneath the vinyl; this will also improve the acoustics in a room. Vinyl floorings split if treated very badly but can be repaired.

Wood

Wood block flooring is unlikely to be considered for new laboratories but may be retained in a conversion. If sealed well and regularly then it does not show the dirt and is particularly useful in absorbing sound. If sealing is not carried out then water will be absorbed into the wood blocks, which will distort, rise and dislodge. A non-slip polish also needs to be applied. Stools, even with rubber ferrules, may scratch the wood but not completely destroy it.

Carpet

This, at first glance may seem strange but teachers, who have carpets in their laboratories, have reported how much quieter the room is and that there is less wear and tear caused by stools. Stains do occur, but if a good quality kitchen or industrial grade carpet with water-repellent properties is used, spills can be washed off before they soak in. Carpets may be particularly suitable for schools in the 11 to 16 age group where the use of corrosive chemicals is limited. The use of carpet tiles would be more advantageous as those that become seriously contaminated (e.g. with mercury) or damaged in other ways, could be replaced. However, this will mean purchasing and storing additional carpet tiles when the initial flooring is laid. Carpets should also be run up at the edges of walls and units so that there are no crevices in which dirt can collect.

Stools

Pupils are required to sit on a stool for some time during a lesson. Occasionally they may become bored and take out their frustration on the stool. To balance a stool on one leg is an amazing feat but it applies a large pressure on the floor and continual twisting drills a hole in the vinyl and ruins the ferrules (end caps) on the bottom of the stools. If the metal base of the stool's feet is open then even more damage may be done. Some pupils will undo and remove any visible screw heads. Protruding screws can ruin clothes, especially tights, and removed screws may allow the seat to slide off when next used.

When choosing stools, make sure they are the correct height. Shorter pupils will need taller stools. BS3202 recommends a height difference of 220 mm between the height of the work surface and the top of the stool but in Building Bulletin 80 the DfES suggests 240 to 270 mm. However, the bench and underframe thickness can be as much as 100 mm thick (less if metal framed) suggesting a stool height of no more than 510 mm which some would consider too low. There should be footrests at an appropriate height and shaped seats are more comfortable. However, for wooden stools, this adds significantly to the cost. Stools with backs provide more support for the lower back but they cannot be placed under the bench when pupils commence practical work. They are left in the gangways and can present a considerable hazard. Some types of stool may be stackable, although how helpful that would be in most laboratories is questionable.

Wood seating

		
This is the standard wooden stool. The wide legs and protective ferrule should, however, cause little damage to floors. It has a pleasant appearance. Wooden stools can be bought with a back support but they will be more expensive and they will not go under the bench.		This is a mixture of the wooden seat but with metal legs. Some designs have had screws in the seat which pupils may be tempted to undo.

Plastic seating

			
The stools have a polypropylene, shaped seat based on tubular steel legs. It is possible to design into the seat some back support although larger supports are available. Metal legs can be noisy when the stool is moved (especially if you are on the floor below).			This stool has a skid base to avoid indentation of the vinyl (especially safety) flooring. It has a cantilever design so it ‘hooks’ onto the bench.

It is important to ensure that replacement plastic or rubber ferrules are available from the supplier and the caretaker keeps a stock of them. If they are not replaced rapidly, considerable damage to the floor will result. One stool manufacturer now suggests the use of steel rather than plastic or rubber ferrules, at least on non-slip floors. These appear to last for a great while and may solve the problem of holes drilled into flooring.

3.9 Eye wash and related facilities

Simple and effective eye-wash facilities can be provided by a short length of clean rubber tubing attached to a laboratory tap at a sink dedicated to this purpose (see chapter 6.3). Such a sink should be adjacent to a bench so that, if necessary, an injured person could lie on it whilst the eye was being rinsed. It's important, too, that the injured person's head can be placed over the sink.

During the refurbishment or building of a school science laboratory a low-cost, plumbed-in eye-wash could be considered since installation costs would be minimal. Misbehaviour has caused problems with such systems in some schools. Schools do not require the installation of emergency showers but cold running water will be required to wash chemicals off the skin or to cool heat burns. This could be provided by the water supply to the eye-wash sink.

3.10 Fire prevention and control measures

Although many science lessons utilise Bunsen burners, the chances of these setting fire to the building are extremely remote. Poor electrical wiring and arson are behind most school fires. Guidance on planning for fire prevention and control is provided in Building Bulletin100: *Design for Fire Safety In Schools* and also in *Fire safety risk assessment: education premises*. Guidance on the legal aspects of fire risk assessment is in PS49, *Fire Risk Assessment in School Laboratories,* which is on the CD-ROM.

Alarm systems

The DfEE in Science Accommodation in Secondary Schools, BB80 advises that "Automatic fire detection is not generally required in science laboratories, however in situations where it is, heat rather than smoke detectors should be specified". In general, smoke alarms, even in the corridor, can be triggered by the use of Bunsen burners. Fit heat alarms instead, but ensure that the trigger temperature should be high enough to cope with the heat radiated by a class set of Bunsen burners in operation.

Some schools have fitted automatic alarm systems in laboratories. These vary in how elaborate they are but those which are part of a whole school system are sometimes linked directly to the local fire station. Smoke sensors in such systems can cause serious interruptions to lessons for the whole school and considerable annoyance to the local fire brigade. Systems can be installed which are triggered by heat during the day and smoke at night when the school is not in session.

Fire doors

Fire doors are often very heavy and cause a major issue for technicians and teachers moving through the rooms and corridors carrying equipment, chemicals and books. They may even be too heavy for the children to open as well. In BB100: *Design For Fire Safety In Schools*, it states "Hold open devices on fire-resisting self-closing doors on circulation routes will allow staff and pupils to move through the building freely. The hold open devices can be integral within the door-closing device attached to the door or stand-alone. In either case they must be connected to the automatic fire detection and alarm (AFD) system so the devices will release immediately when the detectors are actuated and the doors will close. This will ensure that compartmentation is maintained."

Laboratory doors - one or two?

Except in Northern Ireland, it is now not necessary for a laboratory to have two exits if a suitable risk assessment is carried out. However it may be that the laboratory is a part of a fire escape route or there may be a fume cupboard or flammable cupboard close to one door in which case another exit is required. In practice, in new buildings it is normal to provide two exits to laboratories.

Fire fighting equipment

We recommend two 2 kg carbon-dioxide extinguishers and one fire blanket. A sand bucket (normally a receptacle for rubbish!) is not required. When using flammable metals, it is better to have a bag of sand immediately available in case of fire. Dry powder extinguishers are not recommended as they cause permanent damage to computers and lead to such a mess that industrial cleaning will be required. A fire blanket can be used to smother fires, often causing less damage than a carbon dioxide extinguisher, which may blast apparatus across the bench. In Northern Ireland the provision of fire-fighting equipment must satisfy the Building Control Authority.

3.11 Provision for ICT, etc

Pupils need computers for certain activities. Computer suites are not normally suitable for activities such as datalogging, though some dataloggers store information for later downloading. Many schools or science departments own a bank of laptops, which are brought into the laboratory when needed.

Teachers often connect a personal laptop to the lab projector and the school network. Connection points and controls need to be accessible e.g. mounted on the teacher's bench to avoid trailing cables from the wall. Increasingly cameras, sometimes connected to a microscope, are used to display demonstrations to the class. These are usually linked to the projector, possibly via a computer though many could display directly via the projector or via a large television monitor if used away from the front of the room. Consider where such a monitor might be sited to be visible yet not prone to being knocked during practical work e.g. near a fume cupboard or other fixed areas or equipment.

A matt screen may be needed to display images from a camera; the whiteboard may be too shiny. Consider mounting a drop-down screen or an additional screen adjacent to the whiteboard.

Further guidance can be found in sections 16.5 and 16.7 of the CLEAPSS *Handbook* and the guide L250 *Using cameras to enhance practical science*.

In Northern Ireland new laboratories should be provided with an interactive whiteboard and data projector, 4 double ICT points for student use and an additional teacher's point.

4. Furniture, systems and layouts

4.1 The needs of practical work

To provide for and manage effective practical work a laboratory needs:

- tables or benches for pupils to work at where they can be as far from each other as possible (for safety reasons),
- easy access for all to services such as gas, water, electricity and drainage,
- surfaces, easily accessible by technicians, where equipment can be laid out and gathered back in,
- walkways so the teacher can easily reach all parts of the room.

In addition, schools need to ensure that efficient use is made of the often limited space available. In a very large laboratory it may be possible to have a practical end and a theory end and teachers are often very satisfied with this arrangement. It is not likely to be a realistic option in schools where space is at a premium.

If you have never designed a lab, or even if you have you can get a very good idea of how any design will work by mapping it out on paper. Use graph paper and a scale of roughly 10mm to 1 m you can quickly and easily drawn an outline of your room, and include on that outline all doors, windows, fixed furniture and any other obstructions or constraints. It is not difficult to cut out scale size tables and benches and to move them around the room to see just what can be achieved. If this does not appeal you can instead use the ASE computer programme *Laboratory Design for Teaching and Learning*. In Northern Ireland the DENI guidance provides a number of possible layouts.

4.2 Layouts and services

The routing of services

An important issue to decide early on in the planning process is how pipes and cables will reach pupils' benches and whether it is feasible (because of the nature of the building or cost) for services to be provided on all benches. Are services needed on every bench? For most laboratories, gas and electricity will be needed for all pupils but it may be sufficient to have water and drainage in a few places around the periphery of the room. However, this would not be suitable for a laboratory to be used for A-level chemistry.

If services are to be supplied to fixed benches or to bollards the only routes are:

- through ducts in the floor,
- via overhead booms, or
- around the walls.

Ducts in the floor

Ducts in the floor are much the most flexible option for a new build but it is likely to be expensive, noisy and dusty to dig up existing concrete floors. For a room on the first or higher floors, it may be possible to run services above a suspended ceiling of the room below, if the ceiling is high enough. In a new-build situation, floor access outlets are best arranged diagonally across the floor. This allows the room to be 'turned round' (from portrait to landscape) in some future refurbishment, without the need to dig up the floor.

Overhead booms

One or two manufacturers have produced systems in which the services are supplied via overhead booms. In practice, these have proved to have a number of problems.

- They have not proved robust enough for use in some schools.
- They are unsightly, give a rather claustrophobic appearance to the room and can restrict sight lines.
- They may be more vulnerable to vandalism.
- Drainage for water supplies has to be pumped away, which may be noisy and has presented costly maintenance problems; sometimes there have been complaints of smells.

A number of schools that had such systems have subsequently removed them. If used, they are far more suited to physics laboratories than chemistry (which need to make much more use of water and drainage facilities). They work satisfactorily where the laboratory has a separate theory area. A combination of water and sinks around the perimeter and overhead gas/electrical services can work satisfactorily.

Around the walls

Because no services are available on pupils' benches or tables, practical work has to be confined to benches around the perimeter of the room. This means that books and papers may be kept on clean, dry tables away from the practical area but often, the tables are butted up to the side benches in an attempt to increase the area available for practical work. Such arrangements can work satisfactorily where classes are small (e.g. as in some special schools) but, with normal-size classes, it tends to result in pupils being far too crowded for safe working. It also means that pupils are working with their backs to the teacher, which does not help discipline or safety. Sometimes, where gas taps are only available on wall benches, schools attach long lengths of tubing to Bunsen burners so that the burners can be used on tables projecting at right angles to the wall. We do not consider this to be a safe arrangement because pupils may not be able to reach the gas tap in an emergency and trailing tubing is itself a hazard. There are similar problems with trailing electrical cables.

A peninsula unit can bring services from the walls into the body of the room. Having peninsulas projecting from the walls is less inflexible than it might seem and this is a relatively cheap way of providing services to pupil benches when converting an existing laboratory. Sometimes, quite extensive daisy chains can be formed, although this may restrict movement. If space is limited (i.e. the room is too small) then a peninsula arrangement can make the most effective use of what is available. However, a teacher's access to the corners may be rather restricted.

Furniture and layout

In practice, modern laboratory layouts tend to be a compromise. During whole class teaching sessions, most of the pupils end up facing the teacher, but a significant proportion have to sit sideways. This will affect their sight lines to the whiteboard and they may have to turn their necks to an uncomfortable angle. If the class is large, a few pupils may have to sit with their backs to the teacher but, at the design stage, this should not be regarded as acceptable. Before agreeing any plans work out what proportion of the pupils will face the teacher and what proportion will sit sideways. Several detailed examples of layouts appear in *Building Bulletin 80* and are well worth studying, although several designs have pupils with their backs to the teacher. This occurs when 30 pupils are accommodated around 4 bollards; 6 bollards offer more flexibility and are a much better option.

Building Bulletin 80 does tend to emphasise the importance of adaptability. It is important to distinguish between short-term and long-term adaptability. Short-term adaptability refers to the possibility of the teacher moving the furniture round according to the needs of a particular lesson. For example, tables might be arranged in a U-shape for a class discussion, all separated for a test, arranged in blocks for group discussion and in long rows for practical work with dynamics trolleys running down ramps. In practice, teachers rarely make use of this flexibility on a day-to-day basis because it is too time-consuming, noisy and disruptive to move tables. However, it is useful if the layout can be altered in response to the behaviour of pupils or changing fashions in teaching style or for special occasions such as open days.

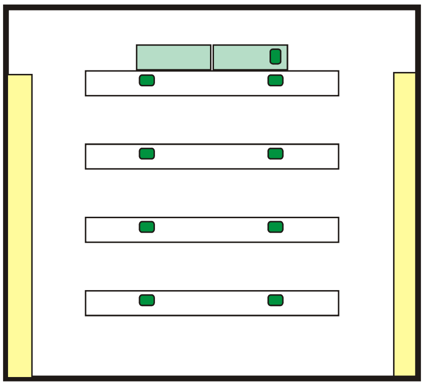
Long-term adaptability means that the furniture comes in kit form, which can be taken apart and moved elsewhere if, for example, a laboratory is no longer needed. In effect, the idea is to recycle the furniture. In practice, however, if a laboratory has been in place for 10 years, it is nearly always cheaper to buy new furniture rather than face the cost of dismantling the old furniture carefully. In any case, after 10 years, such furniture is likely to look well worn.

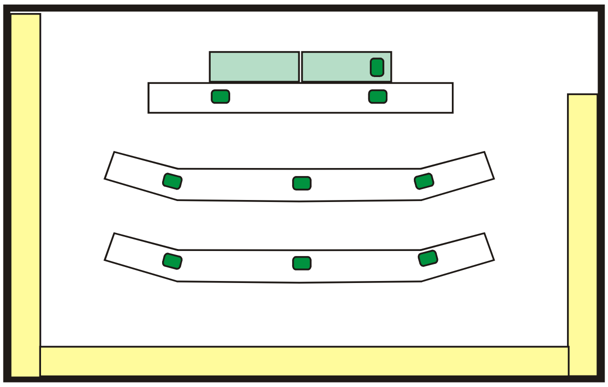
Despite advantages, we think that adaptability, both long- and short-term, is less important that is sometimes suggested.

Examples

In the following illustrated examples (which are better viewed on a screen) we have tried to ensure that pupils are facing the teacher and have adequate access to a sink. There is a minimum distance of 1m between the tables and the side benches.

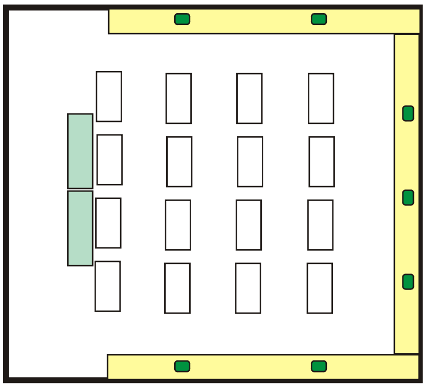
Fixed benches with underfloor services

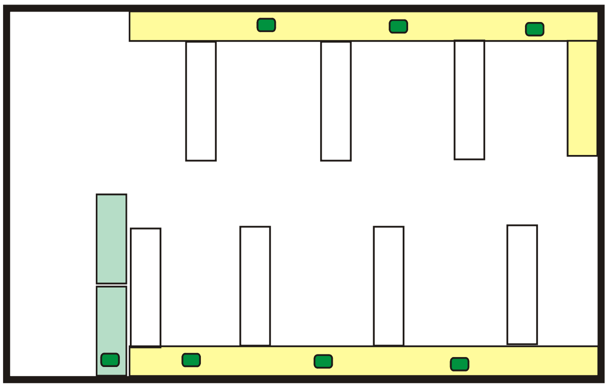




Some schools still like traditional, long, fixed benches arranged as in either of the above diagrams. Often cupboards containing equipment are installed under the perimeter benches. Such fixed benches may mean that it takes longer than desired for teachers to reach pupils in an emergency. For this reason the walkways between benches must remain clear. The use of peninsula benching solves this problem. There is no flexibility with the design, which may affect some teaching styles.

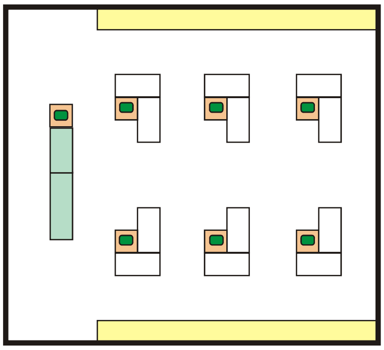
Fixed benches with services around the room





The services are around the room only. A significant health and safety issue is that pupils will be doing practical work with their backs toward the teacher. With the peninsula design on the right they may also be rather squashed together. For the teacher's bench to have its own services it must be linked to the wall as in the second design.

Service pedestals with tables

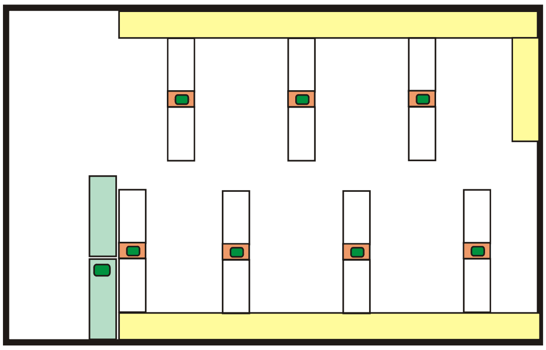


Many modern laboratories are built around the idea of a service pedestal, with perhaps 4 or 6 of these arranged as islands at strategic places on the floor. Service pedestals are fixed to the floor and are now almost invariably 600 × 600 mm. Even with the larger pedestal, some schools have found it necessary over time to fasten the pedestals to the floor with additional bolts. (A design for a robust fixing plate appeared in the CLEAPSS *Bulletin* 100, Autumn 1997).

Rectangular tables, usually 600 × 1200 mm, are arranged around the pedestals in a variety of patterns. If the gap between pedestals is an exact multiple of 600 mm then very flexible layouts can be achieved, including, if desired, long rows as well as smaller blocks. With block arrangements, it can be difficult to avoid some pupils in larger classes sitting sideways on to the teacher, or even having their backs to her/him. The whole point of the system is that moveable tables provide a degree of flexibility. However, some schools have decided to bolt smaller tables to the floor, to cut down the noise if they are moved and to prevent the tables rocking on uneven floors.

Tables sold today are usually metal framed because these are cheaper than wooden frames. They also give more legroom because the legs are narrower than the wooden equivalent or they may be cantilevered. A steel frame makes such tables unsuitable for work with magnets and compasses. A-level physics groups sometimes report having to work in the corridor to avoid interference.

Service pedestals with tables and fixed benches



In this design services are routed around the walls and fed along a fixed bench along to the service pedestal. The outer table at each pedestal can be made fixed or be loose as required.

Octagonal units

Octagonal-shaped units bolted to the floor have become popular in place of rectangles. Sometimes the octagons function as separate islands, but pairs are common. The octagons will have gas and electricity (sometimes on a raised platform in the centre) with water and drainage available at a linking unit between two octagons (creating a sort of dumbbell shape). A raised platform can make it difficult for the teacher to see what a pupil is doing. It also wastes space as it is often too small for pupils' books and folders. Sometimes octagons form a daisy chain of perhaps 2, 3 or even 4 linked units (which suffer from even worse access problems for the teacher than traditional long benches). There are the same limitations on bringing services under the floor, as are described above, so there may be peninsular arrangements.

It may seem obvious but an octagon with 8 sides can sit 8 pupils. If one or two sides are removed to connect to other octagons or to perimeter benches via rectangular bridging units then there will be only 7 or even 6 places for pupils. Illustrations of layouts in the brochures of some suppliers can be very misleading, with, say, 8 pupils arranged around the 7 remaining sides of the octagon. We would advise schools to look very carefully at illustrations. If pressed, some suppliers may suggest sitting the 8th pupil on the rectangular bridging unit, but this is not practicable if there is a sink in the middle of it and, if there is not, there may well be no knee space.

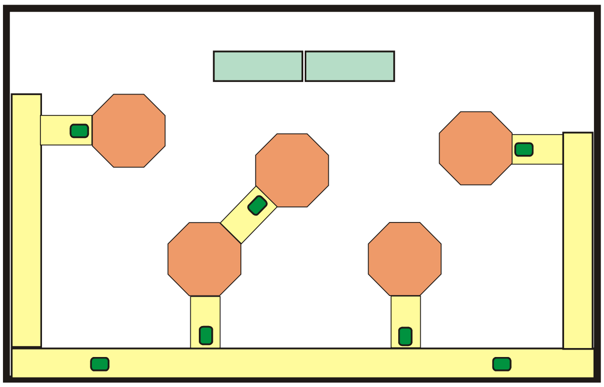
Undoubtedly some teachers like octagons – they look modern and impressive in school brochures. The arrangement with 6 to 8 pupils facing each other helps facilitate group discussion. However, unless classes are unusually small, or there has been unusually generous provision in the number of octagons, many pupils end up with their backs to the teacher. With well-motivated pupils this may not be a problem but most schools do not like pupils sitting with their backs permanently to the teacher. One school avoided this problem by insisting that the sinks in the linking units were offset so pupils could sit there. One local authority provides 6 octagons in a laboratory, with some moveable tables, and this easily copes with 32 pupils. Several independent schools with classes of 24 or less are happy with 4 octagons. Most of the discontent arises from combinations of large classes and only 4 octagons.

Apart from pupil-seating arrangements, there may be health and safety and other disadvantages, too. With 8 pupils working around the same table, if an explosion occurs or if chemicals spurt out of a badly-heated test tube, it is more likely that somebody will be in the firing line, than if there are only 2 pupils at a table. Also, an octagonal shape does not make good use of a rectangular room. Large unused – and unusable – circulation spaces are created. The work surface available to each pupil may be less, although this obviously depends on the size of the octagon. Front edges may be as much as 745 mm (which is satisfactory) but they can be as small as 600 mm, or even 500 mm, where efforts are made to squeeze a full class into a small room. Clearly no system can cope with this, but manufacturers claim that, with good design, octagons are better at overcoming the problems. However, a CLEAPSS questionnaire, respondents were about 3:1 against octagons, with typical quotes shown in Table 2. To be fair, there are also strong feelings in favour of octagons, of which representative quotes are also shown.

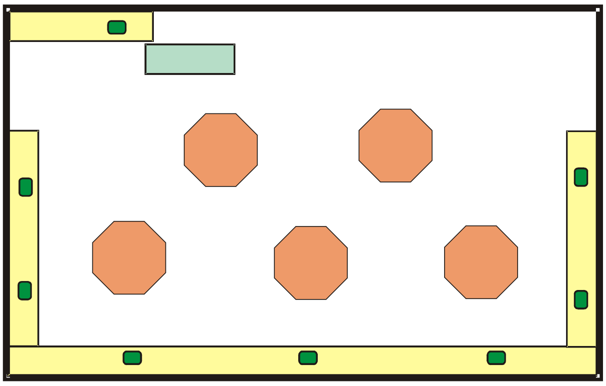
Table 3 Pros and cons for octagons

Arguments against octagons	Arguments for octagons
• Noise levels have increased dramatically since the move. • With older pupils there is no elbow room. • Too many pupils have their backs to the teacher. • Lack of room for some activities, e.g. with metre rule in light investigations. • Gas taps and sockets cannot easily be seen and so malicious damage is not spotted. • Very difficult to prevent chattering. • Safety – very difficult to move around. • No teacher's demonstration bench. • Lack depth for sitting comfortably at stools.	• Superb for practical work. • Smart, modern appearance. • Fits a lot of pupils in. • All pupils near the teacher. • Freer movement when pupils need to fetch apparatus. • Big space for demonstrations. • Ideal for A-level • Pupils give greater respect to the modern design.

Octagons with services around the room



Octagons with underfloor services



It is necessary to keep 1.4 m between the octagons to allow passage between seated pupils. When contemplating octagon designs pay close attention to where the pupils will sit and how many have their backs to the teacher.

Other systems

Some companies have systems involving other shapes of table, for example a hexagon or a mobile half-moon shape on the end of a mobile rectangle, butted up against fixed rectangles. Another company offers triangular service units, around which can be arranged three rectangular tables with half-moon ends. Circular and teardrop-shaped tables also have some advantages. We have too little experience of these to be able to offer much comment but schools considering such options should think carefully about the extent to which comments on octagons might be equally applicable.

4.3 Cupboards, drawers and shelves

It is important to have furniture of the correct height but choosing a suitable bench height for pupils of widely-varying heights is not straightforward. Building Bulletin 80 suggests that 900 mm is suitable for pupils at KS 3 and 4.

Some suppliers have a cantilevered system, where the worktop is supported on a frame independently of the under-bench units. This means that under-bench units can be added or moved at will. A variant on this is the suspended system, where under-bench units are hung from the metal frame. Whilst in theory this makes for easier cleaning, schools which had the system often felt that moving cupboards was not as straightforward as the suppliers claimed.

Drawers (or shelves) under pupil benches rapidly accumulate chewing gum, orange peel and worse. They are rarely, if ever, used for permanent storage, although some teachers like them as pupils can put folders, etc, there during practical work. Drawers under side benches may well be used for storage of small items and, on the whole, work well if pupils are not sitting regularly at the side benches. Cupboards under pupil benches can be useful for storing bags, etc.

Cupboards are not usually placed under moveable tables for obvious reasons. Fitted into pedestal service units they give pupils too easy access to service fittings unless locked. They can be fitted under octagons (as these are fixed to the floor) but frequently are not as they would reduce knee space. Cupboards can be fitted successfully under the teacher’s side of single-sided pupil benches. Knee space is preserved and pupils do not have too easy access to the cupboard.

Shelves will be needed in most laboratories for books but it is now not usually considered safe to store bottles of chemicals in laboratories, unless under lock and key. Glass-fronted cupboards are useful for displaying models, etc. In many schools a filing cabinet will be necessary in each laboratory for storing assessment records, schemes of work, etc.

Quality

Furniture of varying quality is available and is an example where a failure to adhere to the ‘rules of thumb’ listed at the start of this chapter leads to problems. Pupils are hard on furniture of all sorts, which is why school furniture in general needs to be more robust than domestic furniture. Make certain you are fitting your new lab with good quality furniture. Consider not just the materials but how units are assembled and fixed to the floor.

We have had a number of complaints about cupboard doors coming off. Hinges that can open to 270° are more suitable than 180° hinges. Pupils inevitably open cupboard doors forcefully and if the door only opens so that it is at right angles to the cupboard front (180° hinge) then great leverage can be exerted, eventually forcing the screws out. This is compounded in some systems by hinges which have screw holes positioned so that the screw goes close to the edge of the carcass, eventually leading to the wood splitting and the hinge coming off.

Provision for pupils with special educational needs

In an increasing number of schools it will be necessary to make provision for pupils with special educational needs and in particular for wheelchair users. It is possible to obtain benches (with or without services) of adjustable height and if required these should be built into the planning at an early stage. They are expensive and are available from specialist suppliers. (For sources, see the CLEAPSS leaflet PS14 *Laboratory furniture and fittings: suppliers and manufacturers* or BESA web site). Table tops should be grooved to contain spills, as pupils in wheelchairs will be unable to jump out of the way. More information is also given in CLEAPSS guide L77 *Science for Secondary-aged Pupils with Special Educational Needs*.

4.4 Teachers' area

In most laboratories it will be necessary to identify where the teacher will be based. This should be adjacent to the whiteboard and the emergency cut-offs, which should all be located reasonably close together. It is also sensible to locate fire extinguishers in this area. It is often suggested that emergency cut-offs should be close to the door but in some schools they may be too vulnerable to interference. It will be necessary to carry out a risk assessment taking into account the likely behaviour of pupils.

The teacher will need storage space, at least some of it lockable. Teachers also need a space for carrying out demonstrations, although in some layouts it may be possible to use pupil benches.

4.5 Suppliers and fitters

Most suppliers can now supply units in a variety of configurations and with a range of bench surfaces. Most will offer a laboratory design service; some charge for this, others do not. Some specialise in laboratories – in hospitals, universities, or research. Some specialise in the schools market – primary and secondary, libraries and laboratories. Others are general furniture suppliers. Some are national suppliers, others just serve a local market. Some supply the prefabricated parts but subcontract the fitting to local agents, whereas others use their own fitters. A local company may have relatively little experience of doing laboratory work but, on the other hand, being local, may be keen to please. Small local companies may offer a design and fit service, purchasing units from major suppliers. A company which is not local is more likely to subcontract the fitting to avoid the cost of hotel accommodation for its own fitters. It is worth trying to find out about the after-sales service that a company offers.

Because there are so many combinations of suppliers and systems we have found it impossible to evaluate the quality of work done by particular companies. Sometimes schools complain about the quality of the work or fittings but on checking the original specification it becomes clear that schools have been supplied with exactly what they ordered – perhaps not what they later wished they had ordered.

CLEAPSS provides and regularly updates a short leaflet for PS14 *Laboratory furniture and fittings: suppliers and manufacturers*. Most of the firms listed are likely to be members of BESA (the British Educational Supply Association). For the most part, information in PS14 has been supplied by the company concerned but where we have been able to form some judgement there is a comment in the last column.

5. Bench surfaces

5.1 Benches in schools and colleges

The expense of buying and installing a bench surface in a laboratory demands that it must last for many years. During its lifetime in schools, the bench will be subjected to a series of abuses, both accidental and deliberate. The bench surface will:

- have chemicals spilt upon it, despite careful management by teachers, because pupils, especially the younger ones, are inexperienced in handling chemicals,
- be wiped at the end of each practical lesson in the interests of hygiene and to reduce contamination; the surface must therefore repel water especially around the vulnerable areas close to sinks, where hands are washed or apparatus is rinsed,
- have hot objects placed on it, ranging from glass beakers containing boiling water to red-hot crucibles,
- be subjected to knocks, bangs, scratches and abrasions caused by heavy apparatus (e.g retort stands) and stools; caretakers and cleaners like to have stools placed on the benches as this results in quicker and more effective cleaning but unfortunately the stools scratch the surface,
- be deliberately burnt, scratched and carved by some pupils.

A new surface is a pleasing sight. It is a shame that accidents, wear and tear and vandalism spoil it. No matter how observant and careful a teacher is, a bench surface will suffer during its lifetime but schools will certainly expect benches to be used for well over 20 years. The bench surface, therefore, should be resistant to chemicals, water, hot objects and abrasion. However, it should also be quickly and easily repaired. The perfect bench surface for schools at a reasonable price does not exist, so compromises have to be made in the light of investigation, experience and local priorities.

5.2 Iroko: the traditional wood for bench surfaces

Tropical rain forests

In the early 1990s, CLEAPSS began to investigate alternative surfaces to wooden benching (usually iroko) because many local authorities were concerned about the sustainability of tropical forests.

Tropical rain forests are being cut an alarming rate and not being replaced by younger trees. Countries harvesting timber (e.g. Ghana) have now installed organisations to monitor the situation and have programmes for planting new trees. The UK has policies that require that the timber used comes only from a sustainable source. From April 2009 there will be a requirement to procure timber that is grown sustainably. The Central Point of Expertise on Timber Procurement's (CPET) web site provides further information and advice on meeting the UK Government’s timber procurement policy requirements.

You can find a list of suppliers of Iroko on the Timber Trade Federations (TTF) web site. Members of the TTF have all signed up to the Code of Conduct that commits them to source from well-managed supplies. If iroko supplies are limited, other timbers with similar properties (e.g. merbau) might well be suitable so it is worth knowing why iroko has been used for laboratory benching.

Properties of iroko

Iroko is tried and tested. It has certainly survived well with some benches being more than 50 years old. Its properties centre on its resistance to water.

Table 4 The effect of water ingress in various woods

	Maple	Beech	Iroko
Moisture content of wood in air with 90% humidity	21%	20%	15%
Moisture content of wood in air with 60% humidity	12.5%	12%	11%
Corresponding tangential movement along the grain	2.6%	3.1%	1.0%
Corresponding radial movement perpendicular to the grain	1.8%	1.7%	0.5%

Iroko resists water ingress better than temperate hardwoods. Seasoned wood is not stable. It expands, contracts and warps with changes in its water content. Water has an affinity for the glucose units in cellulose and this causes the units to be pushed apart. Although normally reversible, extreme flooding can cause the fibres to become completely separated. Table 4 refers to wood achieving equilibrium with different water levels in the air. It shows that less water is absorbed by iroko and that movement of cellular components is small, less than one third of that of European beech and Canadian maple (see *Wood Preservation* by B A Richardson).

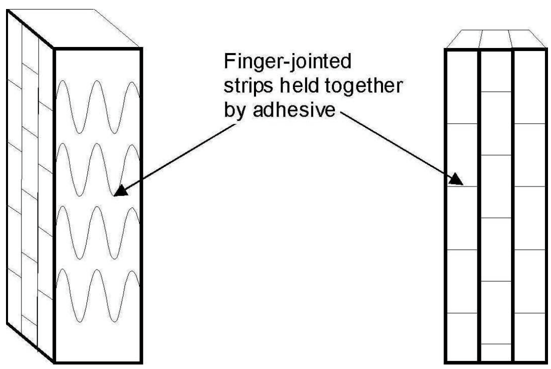
The effect of water on woods is particularly relevant to areas around sinks, especially as water vapour is also rapidly lost or gained through the end-grain surfaces as well. This results in the wood splitting and the development of fungi, causing staining and decay. Veneers are particularly prone to this problem (see *The International Book of Wood).*

Just as iroko repels water, it will repel aqueous solutions of chemicals. However, if the solution is not wiped away immediately, the chemical may begin to react with the surface finish and ultimately with the wood itself. Acids and alkalis react with cellulose, breaking the polymer down into smaller units, weakening the wood in that area. Other reagents, such as oxidising agents, attack all the chemicals in the surface while organic solvents dissolve away the resins.

Other woods (e.g. beech) could be used for tables where practical activities not involving chemicals take place.

Using younger trees

As it takes 40 years after planting for iroko trees to grow to maturity for logging, the slowness in return on the investment into reforestation is not helpful to a country's economy. However, planks or sheets can be made from wood taken from trees that are only twenty years old. Small solid finger-jointed strips of wood are glued together with a strong adhesive. In our immersion test, this version did not come apart, nor warp as normal iroko samples did.



How it is put together

How it appears

Woods from temperate climates, e.g. beech, can also be built up into planks in much the same way as iroko. Immersion tests showed that the blocks can come apart. As woods are usually coated with lacquers or oils to prevent water ingress, this would not happen for some time but areas around sinks may soon be prone to splitting.

Protecting wood surfaces

It is imperative that wood is sealed to prevent or resist attack by water and chemical reagents.

A finish should:

- repel water and aqueous solutions initially so that, if immediately wiped away, the active chemicals in the solutions do not have time to be absorbed into the fibres of the wood and then react with them,
- be resistant to abrasions,
- be repairable quickly, safely and by people with perhaps little time and/or experience in working with wood.

The finishes available are listed in Table 5 along with comments that CLEAPSS has received about their use in schools. There are various types of varnishes and oils. Oils based upon tung oil are less greasy than linseed oil, but regular oiling is required.

Table 5 Various finishes on iroko

Property	Lacquer	Varnish	Oil
Appearance	Gloss or matt. Very pleasing appearance.	Gloss or matt.	Matt.
Water repellent?	Yes.	Yes.	Yes but continual washing will remove oil.
Effect of chemicals?	Dilute solutions have very little effect. However, it is attacked by concentrated acids and alkalis.	It can be attacked by dilute alkaline solutions and organic solvents.	It is attacked by dilute alkaline solutions and organic solvents.
Effect of a hot crucible?	Lacquer decomposes and the wood shows a burn mark.	Varnish decomposes and the wood shows a burn mark	Wood shows a burn mark.
Can it be scratched?	Yes. Dilute alkalis and organic solvents can then attack the exposed wood.	Yes. The layer of varnish can be peeled away to expose more areas. Dilute alkalis and organic solvents can then attack the exposed wood.	Yes. Dilute alkalis and organic solvents can then attack the exposed wood.
Can the surface be repaired in house?	Not without expert help. It will take several days and is best done during school holidays.	Yes. Small areas can be very easily sanded and recoated. After coating larger areas, harmful fumes will be given off. It could take a number of days if two coats are applied.	Yes. Small areas can be very easily sanded and recoated. After coating larger areas, harmful fumes will be given off. It could take a number of days if two coats are applied.
Other comments	Very expensive unless a part of the original package.	Moderately expensive depending upon the labour used. Some areas need to be revarnished every year.	Least expensive depending upon the labour used. Some areas need to be reoiled every year.

Are synthetic surfaces a green alternative?

Just because synthetic surfaces do not use tropical hardwoods, does not mean that they are suitable alternatives. Remember that:

- wood is a renewable resource, if the forests are managed efficiently, whereas synthetic materials are often derived from oil, a non-renewable resource,
- considerable energy is used in converting oil to the synthetic substances,
- if forests are given no value to a local community, then they will be removed forever and land made over to other cash-crop farming. Allowing countries, such as Ghana, to manage their forests sensibly, provides local employment and valuable export revenue,
- the Overseas Development Agency and the World Bank recognise that timber exports are a key element in the economy of developing countries.

5.3 Synthetic surfaces

Introduction

Synthetic surfaces are derived from oil-based chemicals. Comments from schools vary from the ‘greatest thing ever invented’ to ‘bring back iroko’. It is therefore difficult to make a ‘best-buy’ recommendation. Much depends on the attitude of teachers, technicians and pupils towards their new teaching environment.

Surfaces available include:

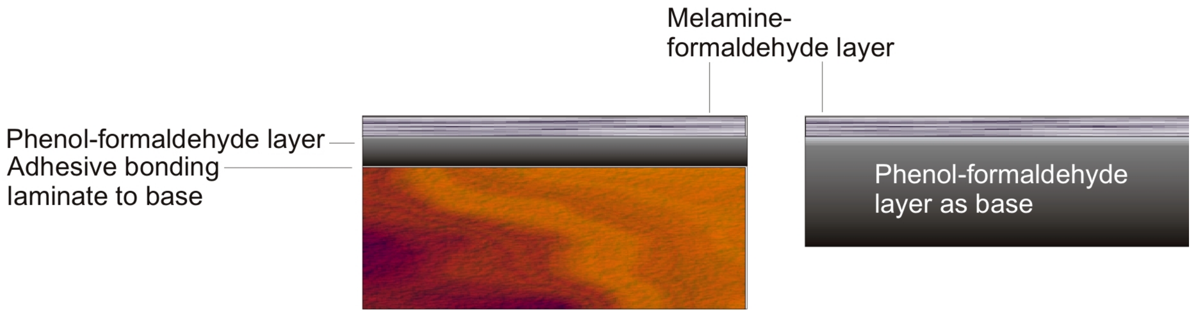
- A thin layer of melamine formaldehyde supported on layers of phenol formaldehyde, which might, in turn, be supported on MDF or a similar wood-derived base,
- acrylic (polymethyl methacrylate) or polyester resins, filled with mineral particles which may be supported on an MDF base,
- polyepoxides (cast epoxy resins).

Formaldehyde-based laminates

(e.g. Trespa Athlon, Trespa Toplabplus, Formica Compact, Formica Chemtop2, Abet Labgrade.)

Thin sheets of paper are impregnated with formaldehyde resins. The surface layers, which can be dyed different colours, consist of a melamine-formaldehyde resin. Under this layer are the darker phenol-formaldehyde layers (see diagram overleaf). The most durable of these worktops are made only of these two resins and are often referred to as solid laminates. They use a thick phenol-formaldehyde layer (12 to 20 mm thick) and cannot be degraded by water ingress.

Less expensive worktops, such as those in kitchens, use a thin double-layered surface (0.9 mm thick) glued with a strong adhesive at high pressure onto an MDF, plywood or chipboard base (about 16 mm). For laboratory use, these should be avoided because of the difficulty of ensuring that water cannot enter the material, particularly at edges and near sinks. Water ingress causes the glue to soften and the surface layer comes away from the base. It is possible to seal the edges completely with timber and by using a post-formed surface to combat water entry, but we are not confident even then that such surfaces can withstand the rigorous demands of science teaching and learning. (Post-forming is the process of bending the laminate around a curved surface with no visible seams.)



Laminate bonded
to an MDF base

Solid
laminate

Laminate on chipboard base with a post-formed edge

Great claims are made about the chemical resistance of the laminates but in schools thermal and mechanical resistance are as important. The principal disadvantage of laminates is that the surface can be permanently damaged by hot crucibles, hot tongs or, even worse, a Bunsen burner flame deliberately applied to the surface. The surface will burn and may crack. In addition, because pupils drop equipment or bang stools onto benches the surfaces have been known to chip. Benches with the thinnest resin layers are most at risk.

At least one manufacturer has impregnated the surface layer with silica to improve resistance to abrasion (Trespa Toplabplus).

These laminate benches are widely used in schools because they are relatively cheap. However, if flame or impact abuse is likely designers would be well advised to choose an alternative.

Mineral-filled acrylic or polyester resins

(e.g. Corian, Surrell, Diorite, Karadon, Swanstone, Wilsonart, Velstone, Sirface, Athena and Coveran.)

The mineral particles (usually hydrated aluminium oxide) are bonded together with resins such as an acrylic or polyester resin or mixtures of the two. Fire resistance of these materials is variable but is greater than for the formaldehyde-based laminates. Under test, those surfaces that did catch fire extinguished themselves after a few seconds.

When first used as a solid for laboratory benching in the 1990s, some cracked because people perched on an unsupported surface or seated pupils tried to lift the bench with their knees. Now, thinner layers of the resin are bonded to an MDF base which makes the bench tops less likely to crack when subjected to mechanical or heat stress and, coincidentally, much lighter. The solid resins are still used as surfaces in fume cupboards and sinks.

Recent advances include integrating mineral fibres into the matrix to improve mechanical stress. This means that less material is used to attain adequate stress resistance and the product is less expensive. You may be given samples to test. By all means do this, but keep the samples to ensure the surface used in your laboratory is consistent with the material tested.

Mineral-filled resin surfaces are easy to clean, light in colour and have reasonable stain and heat resistance, although they will not resist deliberate burning with a flame. Despite bonding to an MDF base we have not heard of any problems with water-ingress, unlike formaldehyde-based laminates.

Polyepoxides

(e.g. Durcon and Simmons. Durcon offers a range of colours. The standard colours of surfaces manufactured by Simmons are white, ivory or light grey, but other colours appear to be available.)

These are particularly useful as materials for sinks and fume cupboard surfaces. They have excellent chemical and thermal resistance. Tables with solid polyepoxide tops can be quite heavy and the surface feels very cold, which may be thought uncomfortable.

5.4 Abuse

Even in the best-managed schools, wilful abuse can occur. It is not unknown for pupils to direct a Bunsen burner flame onto the surface for several seconds or minutes. Under test, when deliberately burnt using a non-luminous flame, wood and formaldehyde-based laminates will start to be seriously damaged in 15 seconds. The latter will make crackling noises and bits of the material can be projected in all directions. The mineral-filled resin surfaces can withstand serious damage until after 30 s but, after that, they start to char and disintegrate. The most resistant to wilful burning were the polyepoxides which were only slightly affected after 2 minutes of abuse. Students have also been known to vandalise surfaces with penknives, files, scissors etc. No surfaces will survive such abuse. If necessary, most surfaces except formaldehyde-based laminates can be sanded down with sandpaper but will leave a depression where the burn or other damage occurred. If sanding iroko, the sander and others in the room should wear a dust mask suitable for fine particles (e.g. FFP2S) because the fine dust particles are known to be hazardous.

Accidental abuse by chemicals, hard objects (including stools on benches, retort stands etc) or burns by hot crucibles, tongs and electrically-heated wires are more common forms of abuse. Table 6 shows the results of some tests carried out at CLEAPSS.

5.5 Brighter colours but…

Synthetic surfaces are usually available in a wide range of colours. Lighter colours make rooms brighter and various colour schemes can be designed. However, the lighter the colour, the more the stained and burnt areas will show. Many surfaces have a mottled appearance that can be helpful in not showing stains so readily. However, it is also more difficult to locate areas where a chemical has been spilt, possibly leading to further damage, getting chemicals onto clothes or even injury if the spill is not noticed and wiped up. In addition, shiny surfaces can lead to glare. CLEAPSS recommends dark matt finishes for bench surfaces where practical work is carried out.

Iroko wood may start reasonably light in colour but darkens with age.

Table 6 Abuse of bench surfaces

Material	Resistance to chemicals	Resistance to abrasions	Resistance to burns
Iroko wood	Resistance depends on the finish. Dilute sodium hydroxide solution affects the finishes most. See Table 5.	Abrasions can cause unevenness on the surface. A scratch can be disguised by resealing.	Wood will char if red-hot objects are placed on it. The burn may be quite deep. The surface is not repairable and sanding will leave a depression.
Formaldehyde-based laminates bonded to a base (MDF, chip-board or plywood)	Water will soak into unprotected edges of the wood and expand the layers. The surface will then come away from the wood base. Comments about unbonded formaldehyde-based laminates also apply (see below).	The base can be exposed if the upper layer is severely scratched.	A hot crucible separates the paper layers in the 0.9 mm laminate. Repair is not possible.
Formaldehyde-based laminates, *not* bonded to an MDF or similar base	The surface initially shows a high resistance to most chemicals but, after attack by a concentrated acid or being scratched, the surface holds stains more readily. Silver nitrate solution attacks the surface very slowly, taking 24 hours to produce a dark stain[2].	It takes considerable effort to expose the lowers layers of the resin. If the upper layer is light coloured, a scratch will appear dark as the lower layers are exposed.	A brown mark is left behind on the surface. If the object is red hot, the resin may bubble and flake away. Repair is not possible.
Mineral-filled resin surfaces	Most chemicals do not affect the surface though concentrated sulphuric acid leaves a white patch, silver nitrate stains the surface brown and, in reflected light, it is possible to see smears from organic solvents. Areas where the surface has been scratched absorb methylene blue and iodine more readily but the mottled design used on this material is such that these problems will be camouflaged.	Repeated placing of stools on the surface causes some chipping. If a knife, for example, scratches the surface, the damage can be sanded out using coarse wet and dry paper followed by a finer grade.	The hot crucible test leaves a white ring. The damage can, however, be repaired using a special kit, although some suppliers will insist on coming in to do the work themselves.
Polyepoxides	Concentrated sulphuric acid attacks the surface but this can be sanded down.	When metal objects (e.g retort stands) are dragged along the surface (especially if light in colour) then scuff marks can be seen. Scratches appear white at first but all these problems can be overcome using scouring powders and a damp cloth.	Hot objects have little effect on the surface; even a red-hot crucible left only the slightest of marks. Deliberate abuse by a Bunsen burner flame will eventually cause damage.

[2] Silvosol® removes silver nitrate or iodine stains. It can be obtained from Rotec Scientific Ltd, 10 Bridgeturn Avenue, Old Wolverhampton, Milton Keynes, MK12 5QL; tel 01908 223399; fax 01908 223000.

5.6 Thickness

It is tempting to cut costs by using a smaller thickness for a bench surface especially if it is made of an expensive material. Cracks have occurred when the bench has a cantilever design and is not supported by a cupboard or a framework. This even occurred with teachers sitting on mineral-filled resin benches in a nonchalant manner. Iroko should be at least 25 mm thick. Laminates without a base of MDF etc should be at least 16 mm thick. Some of the mineral-filled resin surfaces are as thin as 3 mm on a 25 mm MDF-base; and this appears to take the strains quite well. Other makes use a 13 mm thick surface on a 25 mm base which, up to now, has caused few problems with regard to cracking (see picture below).

5.7 Costs of different surfaces

The relative cost of different materials for bench surfaces has changed over recent years. *Building Bulletin 80* did suggest an order of costs but this is not likely to be valid any longer. What is important is:

- if you have already selected one particular type of bench material, that you obtain more than one quote for the supply or work,
- if you have not decided on what bench material to specify, ask you supplier to quote for different types.

Laminates bonded to a base (e.g. MDF) would be a little cheaper than solid laminates. However, some manufacturers have quoted prices to CLEAPSS for laboratories with mineral-filled resin surfaces at only a little more than an iroko-surfaced laboratory. Much depends on the thickness specified so it is important to be sure you are comparing like with like.

6. Services

6.1 Gas

National guidance on gas installations is contained in the booklet *Gas installations for educational establishments*, published by the International Institution of Gas Engineers and Managers (IGEM).

Where a gas pipe enters a laboratory, there should be an isolating valve. There is no requirement for this to be done in existing installations, but any new-build or conversion should have it and sometimes it is desirable to fit it retrospectively. The isolating valve should be close to the place where the gas supply enters the laboratory.

Three sorts of valve are available, in order of increasing cost:

- a manual valve, ie, a spanner or similar,
- an electric solenoid valve which may be remotely switched,
- an automatic system linked to sensors (e.g. 'Gasguard' produced by EFM Flamefast).

A manual valve is appropriate in many situations, especially if it is lockable in the 'off' position. However, it does need to be easily accessible, which may not always be possible. The valve should be suitably labelled with the 'off' and 'on' positions indicated.

A solenoid valve has the advantage that the switch and the valve itself can be in different places and there can be more than one switch. The valve might be outside the laboratory (useful in conversions where pipes could be inaccessible) and the switch could be close to the teacher's area. Any gas fitter should be able to obtain suitable valves. A possible disadvantage would be the loss of gas supply in the event of a power cut. The system is often designed so that a key is required to reset the system after the supply has been switched off. This is usually necessary to provide vandal proofing but could be a nuisance if the key is not readily available. The electrical supply to the solenoid must be on a separate circuit to the main laboratory supply, so that it can be switched off independently.

Automatic systems linked to sensors are relatively expensive. In early installations schools experienced many problems, with gas being shut off unexpectedly or inconveniently, but this appears to have reduced. In any event, some problems can be easily overcome by staff training. Systems include a time clock that switches the gas off out of school hours. This is useful if vandalism is a problem but inconvenient if you want to run an open evening because the controller needs reprogramming. When the time clock switches on in the morning, pressure sensors check whether any gas taps are open, and the system switches off automatically if there are. It was this feature which proved initially difficult because of the need to set the system to detect the difference between 16 Bunsen burners connected correctly and one open tap with nothing connected. It is claimed that this problem has been solved.

Building Bulletin 80 recommends one gas tap per pupil. The gas taps should be on the tops of benches, never on the sides. Gas taps should be positioned so that pupils do not need to use long lengths of Bunsen burner tubing. The taps should have either drop-down or spring-loaded keys so that they cannot become 'knocked on'. The on / off positions should be readily visible to a teacher or technician. The taps should be securely fixed on the bench but the screws should not be visible because students have been known to unscrew them. *The Gas Safety (installation and use) Regulations* demand that all work of this nature should be carried out by competent engineers (such as those that are *Gas Safe* registered). CLEAPSS strongly recommends that anti-rotation devices (e.g. Liverpool plates) are used so that gas taps will not rotate when mishandled by pupils. Beware that fitters sometimes fail to install gas taps in accordance with the designer's intentions so safety devices may be circumvented.

If possible, a mains gas supply should be installed. Failing this, liquid petroleum gas (LPG) should be piped in from cylinders outside the laboratory, in accordance with the relevant British Standard (BS 5482-1:2005) and the LPG Association Codes of Practice. Schools that use LPG can obtain advice on storage of cylinders from a *Gas Safe* engineer. As the gas / air ratio for burning LPG is different to that for natural gas, special Bunsen burners and other gas equipment must be purchased.

Hoses, for flexible connection pipes to mobile benches or mobile fume cupboards, should be no more than 1.4 m in length, located outside rising duct work and be suitably and securely connected. Moreover, the mobile unit itself should be restrained with a stainless or galvanised steel restraint cable, securely fixed to the floor, bench or bollard. The length of this cable should avoid excessive strain on the fittings caused by moving the unit.

6.2 Water supply

The Water Supply (Water Fittings) Regulations 1999 replaced various local Water Bylaws to ensure that there is no contamination of the public water supplies. The term 'water fittings' includes pipes (other than mains), taps, meters, cisterns, water closets, etc. Any new fitting now has to carry a CE mark or conform to a Harmonised Standard. If schools wish to alter or extend the water supply to their premises, they should inform their local water undertaker (i.e. the 'water company').

There has been considerable discussion about the requirements of taps and their fittings in school laboratories. The main issues are:

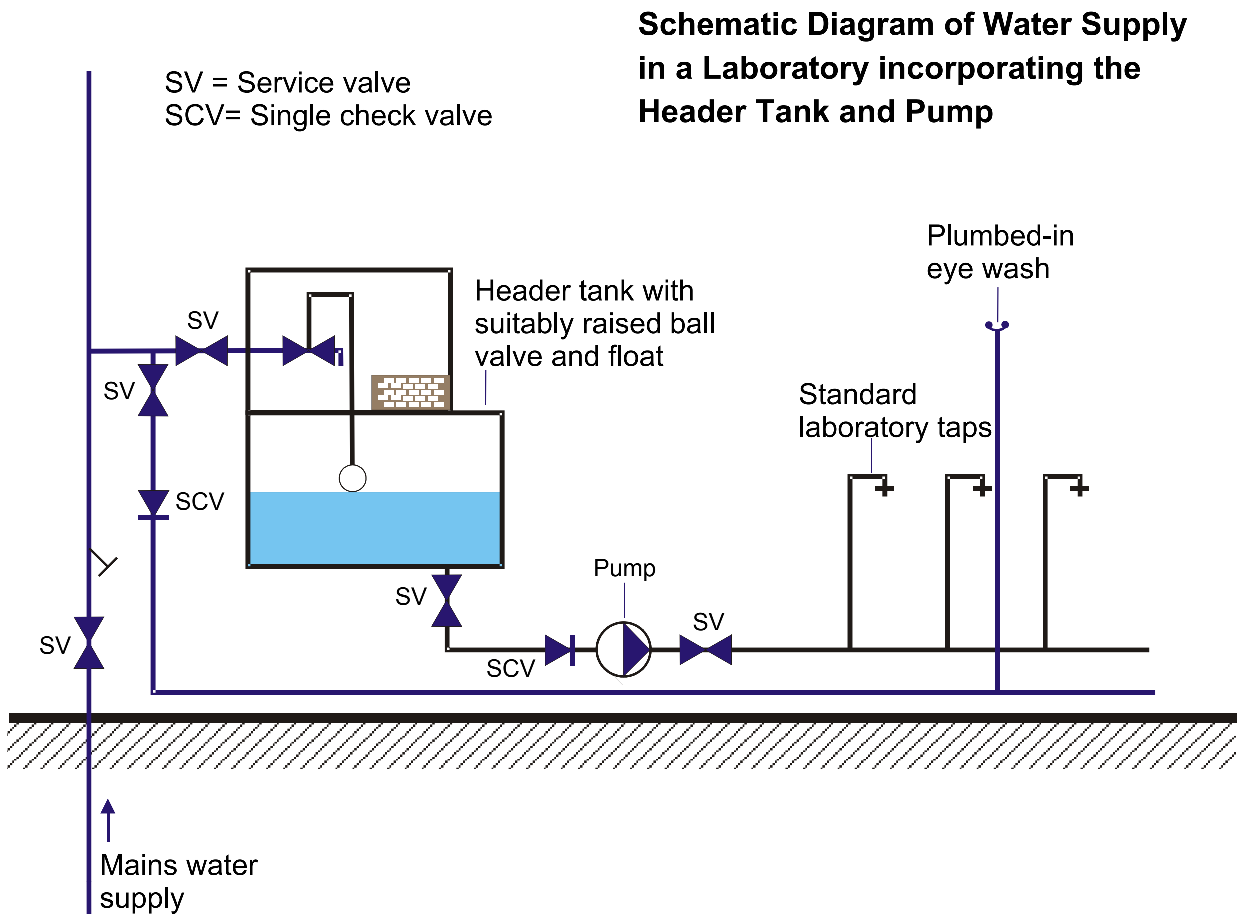
- There must be some means of ensuring that, under all circumstances, there is no possibility of waste water contaminating the incoming water supply.
- Lab taps can, and often do, have lengths of rubber tubing attached which can drape in a sink. These tubes can compromise the air gap between water in the sink and the tap.
- The waste water in the sink could be classified as fluid category 4 – fluid which represents a significant health hazard because of the concentration of toxic substances, including chemical and potentially harmful organisms. Under some circumstances it has been argued that the water in the sink might be as high as fluid category 5 (the most harmful).
- A length of pipe attached to a tap means that it is possible for water in the sink or drain to backflow into the tap and this possibility must now be fully guarded against.
- The simplest means of achieving this is by having a large enough permanent air gap between any waste water and the incoming supply.

A number of air gap devices, fitted into the pipe system or to the tap itself, have been designed and tried but none has proved effective, or indeed sensible, in the context of school science. The best solution, at least to CLEAPSS and to the water suppliers, is to provide the required air gap at the point where the water enters the lab or the science suite. This is achieved through some form of header tank that has a ball valve to control the inflow of water and an outflow pipe to the lab(s). Science suites or laboratories which already have water supplied through a header tank need take no further action. However, since it is current practice to supply mains water directly to taps or appliances in any building, header tanks are no longer routinely installed.

For new labs it is possible to purchase a small compact header tank which will fit under a bench (see figure 3 overleaf). A small electric pump is fitted to the outflow pipe that responds, like those in power showers, by switching on only when there is a demand for water from one or more taps. The pump ensures that adequate water pressure is maintained to supply condensers, stills and water vacuum pumps, and means that the tank can be sited under a convenient part of the bench.

Whatever arrangements are made for the supply of water there should be a control valve (or tap) in each room to turn the water off in an emergency. If, for any reason, the water in the lab is at a high pressure, then water will gush out of a tap too quickly. It rebounds out of the sink or apparatus and on to the surrounding bench area or possibly into the eyes and/or on to the clothes of the people close by. This could be dangerous if the apparatus already contains a hazardous chemical. In such situations a valve in the supply can be used to adjust the flow rate. In any case, for maintenance purposes it is an advantage and possibly, depending on the design, a requirement for the supply to each tap or group of taps to be isolated using a service valve.

Figure 3



The diagram also makes clear that any plumbed-in eye wash station should be connected directly to the mains supply.

6.3 Sinks, taps and drains

Provision

Sinks are required in laboratories and preparation rooms for a water supply for practical activities, to wash equipment, to dispose of low hazard solutions, to wash hands after handling chemicals or living organisms and to apply immediate remedial measures after an accident. At least one sink will require a supply of hot water for hand washing.

If a room were to be fitted with only one sink, then there would be a considerable amount of movement by pupils in the room with all the problems that might then occur. On the other hand, the more sinks that are close to pupils' work places, the more abuse they may suffer, such as removing nozzles from taps, bending the tap stem, and generally using the sinks as a rubbish bin. *Building Bulletin 80* recommends one sink per 6 pupils. A sink is also recommended for the demonstration bench (if there is one), the fume cupboard (if there is one) and another for washing hands and applying remedial measures (see chapter 3.9). The number of sinks for pupils may need to increase if they have to be sited around the perimeter as this may make access to the sinks by pupils more difficult.

Certain operations in chemistry carried out in post-16 courses require a sink to be an integral part of the procedure, e.g. use of a condenser. These sinks need to be positioned near the other services and carefully sited so that long lengths of rubber tubing are not required for connections. Also there should be at least one tap, to which tubing can be fitted, for each pair of students.

Sink materials and size

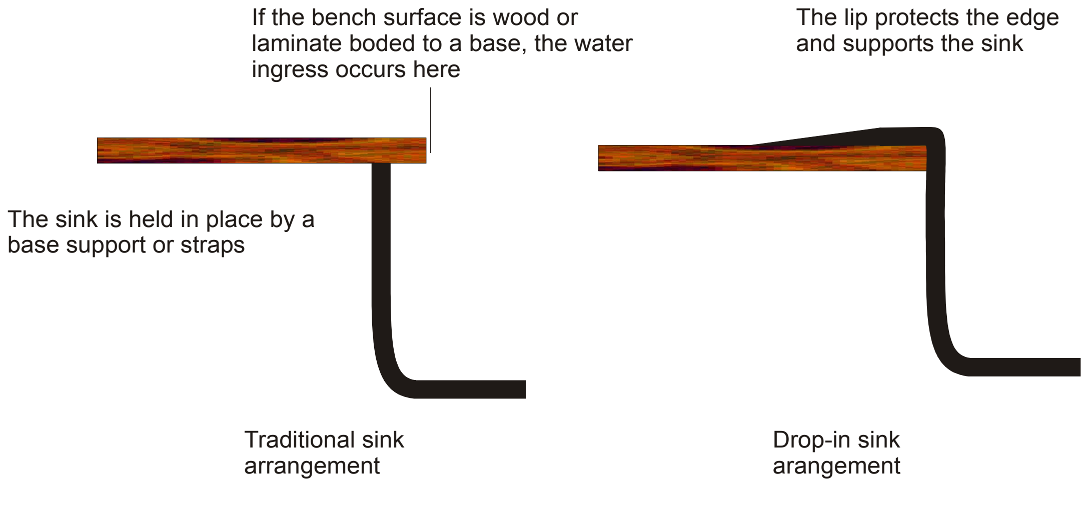
The traditional material for sinks is fire clay which is extremely hard. These heavy ‘Belfast’ sinks are durable, resistant to chemicals and heat, and relatively easy to clean. They have been known to craze and even to crack. Glass apparatus dropped in them shatters readily. Sinks made of other materials are more forgiving. Cast epoxy sinks are highly resistant to both heat and chemical attack. In some cases they may be slightly cheaper than fire clay. Polypropylene sinks resist attack by chemicals, but can be damaged by hot objects. Stainless-steel sinks are attacked by metal particles and corrosion can start. We generally do not recommend stainless steel sinks in laboratories and preparation rooms but if used they should be specified to 316 grade which resists corrosion better than domestic grade sinks (304). Sinks made of mineral-filled resins are also available and have good heat and chemical resistance. If sinks are made of light-coloured materials, they can become stained and dirty unless cleaned regularly.

Sinks for general laboratory use should be of reasonable size. We suggest about 300 $\times$ 200 mm, with a depth of 150 mm. If sinks are too small, water, even at low pressure, will gush out of the tap and splash onto surrounding areas. A larger sink may be required for washing up, if this is not done in the preparation room, perhaps in a dishwasher. Some activities, such as filling bowls or submerging potometers, require a greater depth than 150 mm, e.g. 220 mm. Any larger sink is also best for providing hand-washing facilities which are necessary in every laboratory so that staff and pupils can wash their hands after handling chemicals and living organisms. One hot tap is usually adequate. It should provide water at a temperature that is suitable for direct hand washing (see also section 7.3). Hand-drying facilities will also be needed. Whatever the intention, if paper towels are provided, they will certainly be used throughout the laboratory for wiping up spills. Roller towels are often a better option. Hot air dryers are unsuitable because they will not be able to cope with the demand of a large number of children all wanting to dry their hands at the same time. They are also noisy.

The height of the sink is particularly important in preparation rooms to avoid the technician adopting a stooping position when using the sink.

Sink areas

The bench area around sinks is particularly vulnerable to problems caused by water ingress, if the traditional design (see diagram below) is used, in which the sink fits to the underside of the bench. Continual swelling and contraction and removal of the oils and resins in the wood benches leads to cracks and discolouration. With laminates, the plastic surface layer can come away from the wood base. Grooved wooden draining boards may become badly marked. This arrangement is very common with Belfast sinks.



The use of drop-in bowls and/or sinks), in which the lip fits over the bench surface, protects the edge from attack by water. A sealant is used to stop water entering under the lip. Sinks made of stainless steel, vulcathene and other synthetic materials can be fitted in this way. The lip can be extended so that it includes a drainer.

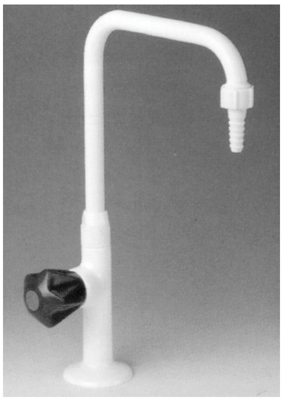
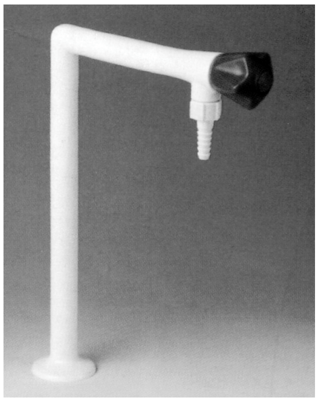
Taps

CLEAPSS strongly advises that fixing or locating plates (e.g. Liverpool plates) are used so that taps will not rotate when mishandled by pupils. Beware that fitters sometimes fail to install water taps in accordance with the designer's intentions, so that anti-rotation devices may be circumvented.

Water fittings can have one, two, three or even more taps and outlets. Each sink should be fitted with one or (if the use is primarily for chemistry) two taps, i.e. a double outlet. The height of the tap nozzle above the sink should be in the region of 225 to 270 mm although this should be higher for taps in the preparation room or on a demonstration bench to allow for taller apparatus being used. It would be useful in the preparation room to have swan necked taps with lower outlets as well as the high outlet (i.e. a triple outlet) so that one of the lower outlets can be permanently fixed to the still. The hand-washing sink should be fitted with pillar taps for both hot and cold water.

There are two designs of taps, the swan-neck or the pillar (see Table 7), which can both be fitted with various nozzles (see Table 8). The illustrations show single taps. Double or triple taps are available but in most laboratories single taps will be sufficient.

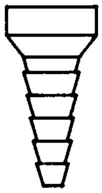
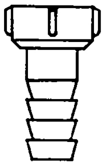
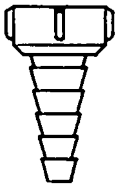
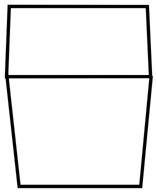
Table 7 Tap designs

Swan neck	Pillar
 *This is a single swan-necked tap.*	  *There are two pillar tap designs available.*
The handle is sited low down on the right or left.	The handle is always central so that there are no left and right-hand models.
Pupils can bend the neck. The swivel outlet can be locked but this might encouraged more vandalism.	There is no rotation and the pillars are more robust than swan-neck taps.
Leaks may occur around the swivel joint.	There are no joints where water leaks out.
The tap is not close to the nozzle and so water continues to drip after the tap is turned off. This encourages pupils to over tighten the tap or flick the drips of water.	The tap is near the nozzle, especially in the design on the left, so once the tap is turned off, there are no more drips.
The tap handle is set back which may be difficult for some pupils to reach.	One design has the tap handle nearer the pupil, which is useful for shorter individuals.

Chromium-plated domestic taps should not be used in science rooms as they may quickly corrode. Epoxy-coated, kitchen-type pillar taps are available from laboratory suppliers. These are tall and lean forward so as not to splash the edge of the sink.

Thought should also be given to the nozzles on the taps. Table 8 shows four varieties.

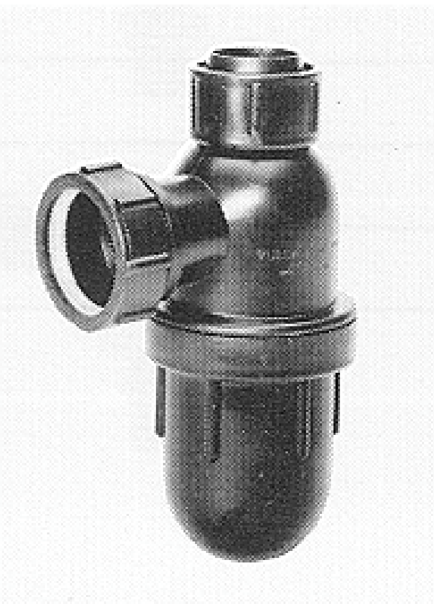
Table 8 Nozzles for taps

			
This is a fixed nozzle with a narrow opening which may become blocked in time with lime scale. Once damaged, the whole tap will need replacing! Suitable for the preparation room and the demonstration bench.	This is a large bore removable nozzle to which only wide bore tubing can be fitted. This nozzle can be removed by students and the thread is easily damaged. The large bore allows water to flow more gently and not splash everywhere. A reserve supply will be required.	This is a removable nozzle to which narrower bore tubing can be attached (e.g. for filter pumps). It can become blocked with lime scale. It can be removed by students and its thread is easily damaged. A reserve supply will be required.	This is a fixed full-bore anti-splash nozzle. Tubing cannot be fixed to it. It is suitable for taps above hand-washing and apparatus cleaning sinks where a reasonable volume of water is required but obviously not if rubber tubing is necessary for eye-rinsing purposes.

Sink traps and drains

PVC is used for drains in domestic situations and is probably suitable for most school science laboratories. More commonly, however, high-density polythene or polypropylene (e.g. Vulcathene) is used as these are more resistant to chemicals and are necessary for more advanced work and in fume cupboards. There should be an adequate number of access points so that blockages can be easily dealt with.

Easily accessible anti-siphon bottle-traps are required under each sink, in order to remove pen tops, broken test tubes, etc. However, as the liquid that schools put down laboratory sinks should not be very much more than dirty water, the much larger dilution traps (or dilution recovery traps), made of vulcathene, glass or even ceramic, are not needed. In fact large traps are a disincentive to frequent emptying.



A bottle trap

A dilution trap
(may also be twice the size and/or made of glass)

6.4 Electricity

Mains supply

Building Bulletin 80 recommends one electrical socket per pupil. Installation should be carried out by competent persons working to the *Requirements for Electrical Installation* regulations, published by the Institute of Electrical Engineers. Guidance was given in GS23, *Electrical Safety in Schools* (HSE, 1990). Although this is no longer published, the HSE has made it clear in recent letters that it regards the advice as still valid. If necessary, CLEAPSS could supply a copy.

Science laboratories will normally require at least two separate 30 amp ring-main circuits to supply standard mains sockets. A detailed drawing should specify which sockets are connected to which main.

The students' ring main, normally supplying sockets on most benches, should be easy to switch off in an emergency or when not in use. One or more additional ring mains should be used to supply other sockets. These could include those on the teacher's bench, any side benches where long-term experiments or animal care systems (such as aquaria) may be set up, refrigerators and cleaners' sockets. Sockets not included in the students' ring main should be labelled to make it clear that the electricity supply is permanently connected (e.g. "Maintained supply").

Separate RCDs (residual current devices, sometimes known as earth-leakage circuit breakers, ELCBs) can be fitted to each ring main if required. Standard 30 mA, 30 ms RCDs are satisfactory. Those with more sensitive settings can sometimes trip unnecessarily with certain apparatus, such as some types of heater and IT equipment.

Fume cupboards should ideally be connected to a separate circuit. They should not be powered from the students' ring main or from any circuit including sockets protected by an RCD. This ensures that, if the students' ring main is turned off or an RCD trips, the fume cupboards (which may contain hazardous gases) will continue working.

Mains sockets are best positioned away from a water supply but this cannot be avoided with certain designs, e.g. pedestal units. In this case, the sockets should be positioned to minimise the possibility of splashes from taps (which should not swivel). It should not be possible for water to flow or drip on to mains sockets. Sockets should not normally be below the height of the bench top. However, where this is the case, physical protection (such as a lip or a hood) should be provided to prevent overflowing or spilt water from coming into contact with the socket. The fitting of an RCD will give further protection where mains sockets are positioned in close proximity to water supplies, but this should be in addition to the measures described above. People are sometimes surprised that it is considered acceptable to have electrical sockets adjacent to a water supply, e.g. on a pedestal unit. However, we have never had reports of any accidents arising from such an arrangement.

It is important to ensure that mains sockets and their housings are sufficiently strong to withstand the treatment from children who may be excited, in a hurry or both. Budget materials that may be appropriate for domestic use will not last long in a laboratory. In addition, the socket housings must be securely mounted to avoid the possibility of fittings working loose. Some types of raised sockets (where the area of the base is relatively small compared with the height of the housing) are liable to suffer damage by rocking and should be avoided.

Low-voltage supplies (up to 24 V)

For science laboratories, portable low-voltage supply units are preferable to a built-in unit, whether the built-in system is centrally controlled (e.g. the old 'Legg units') or takes the form of separate modules (i.e. a more modern trunking system). The reasons are outlined below in Table 9.

Table 9 Advantages of portable low-voltage supply units over a fixed supply

Economical	It is more economical to buy a set of low-voltage supply units than a built-in system (to which must be added the cost of installation).
Flexible use of laboratories	More work areas can be used for low-voltage practical work as portable supplies can be carried from one room to another on a trolley.
Independent working	Portable supplies allow pupils to change the voltage for their own investigations independently of each other. Centrally controlled systems do not allow this.
Maintenance	Portable supplies require standard portable appliance testing. If one portable supply goes wrong, it can be serviced while the others remain in use. Built-in supplies usually require specialist inspection and testing. If a built-in supply goes wrong, then specialist on-site technical support is usually required from the manufacturer and the whole system may be out of use for some time and, indeed, money may not be available for it to be repaired.
Maximum current output	Portable supplies can deliver 4, 5, 6 or 8 A depending on the model chosen. Centrally-controlled systems typically deliver 30 A over 15 outputs, i.e. only 2 A maximum per output.
Vandalism	An act of vandalism on a portable unit, although serious, would not affect the practical work carried out by others in the same room. Portable supplies can be stored away when not in use. Built-in systems present a continuous temptation to vandals.

6.5 Vacuum

A vacuum line is not normally required in schools, although it may be needed in some colleges. If the water pressure is, for any reason, too low or erratic to obtain a vacuum by using water pumps this may be an option worth considering in laboratories used for A-level chemistry.

7. Preparation rooms and storage

7.1 Introduction

Efficient and effective science teaching depends on equipment and materials being in the right laboratory at the right time. In most schools, it is the task of the technician(s) working from the preparation room, to ensure this happens. Thought should be given not only to how much space is required for preparation and storage, but also to ergonomic issues, essential in addressing the manual handling and work needs of technicians.

A preparation room should not normally be an office area for teaching staff to prepare lessons or do marking, If it has to be, provision should be made for separating the areas. Technicians will, for example, be handling chemicals in bulk or engaged in micro-biological procedures, both of which require the utmost concentration and no interruptions. Prep rooms should also not be used or temporary accommodation for pupils, for any reason.

More information on the needs of technicians in the prep room can be found in CLEAPSS Guide L248a; *Running a Prep Room*.

7.2 Strategy and space

CLEAPSS prefers a central store and preparation room servicing all three sciences on the same floor. This means that, in large schools, the technicians can work as a team, security will be improved and the preparation room can be staffed continuously. Many difficult manual handling problems are solved as well. In some central prep room designs, many or most of the labs lead directly off the prep room. Whilst appearing to provide very good access, the prep room walls are perforated by a large number of doors leaving a very limited amount of wall space for benching and storage shelves etc. This sort of design will make the servicing science lessons harder not easier. In busy prep rooms its worth considering providing for an ‘in’ and an ‘out’ door to avoid the possibility of collisions.

Prep rooms not on the ground floor of a building should, if at all possible, be supplied with a lift or a hoist. A small hoist should be sited so that its doors open at a convenient height to transfer heavy objects straight onto a trolley. The doors to the hoist should be lockable to avoid any misuse or rubbish being thrown into the chute.

Having individual subject-based prep and store rooms, such as are often found in older buildings, Independent Schools, VI form & FE colleges, can lead to duplication of equipment (e.g balances) and manual handling problems. Sometimes, in existing installations, such prep and store rooms are situated on different floors, or even in different buildings, which is far from ideal. Supervision, shared working, learning from others and simply working as a team are much more difficult. It also means that one or more of these small preparation rooms may be unstaffed at times.

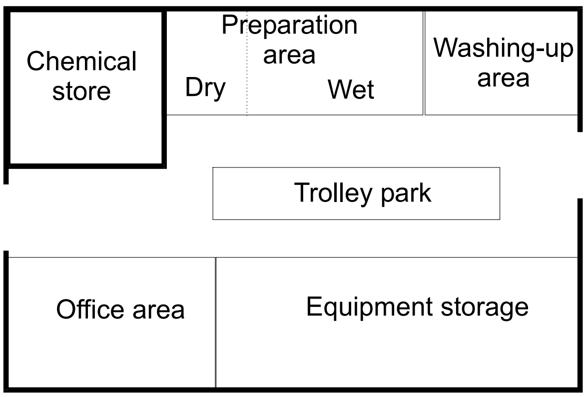
DfEE guidance in *Science Accommodation in Secondary Schools*, BB80 suggests that the amount of space required for preparation rooms and storage should be 0.4 to 0.5 m^2 of floor area for each science pupil place. Therefore, for a suite of six laboratories each holding 30 pupils, the preparation room/storage area should be $6 \times 30 \times (0.4 \text{ to } 0.5)$ m^2, i.e. 72 to 90 m^2, the size of another laboratory. This assumes that there is already 4 to 6 m^3 of storage space in each laboratory (for local resources and display). If the design means that a central prep room has to be smaller than the calculation above would determine, more storage room will need to be found in the laboratories or in smaller satellite or ancillary store rooms. The disadvantages of such arrangements include dirty or soiled equipment often being left in rooms, an increased risk of pupils stealing equipment / materials and the imposition of even greater restrictions if a room ever has to be used as a form base or by non-science teachers.

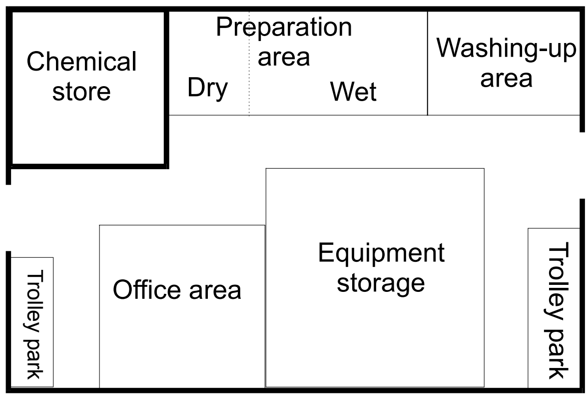
The amount of space needed for different functions is suggested in Table 10 and possible arrangements for a central preparation room are shown in the following diagrams. Chemicals are best kept in a separate chemical store opening off the main preparation room.

Table 10 Allocation of space within a preparation room

Area	**%**
Preparation	17
Washing up	9
Mobile storage	8
Circulation	23
Office	11
Equipment storage	21
Chemical storage	11

Should space be limited, priority should be given to the preparation, washing-up and mobile trolley area. It would be hoped that separate small rooms could be found for the technicians' office and storage areas.





7.3 Activities

Preparation area

Requirements for the preparation area include;

- a fume cupboard,
- a dish washer (or, if you can afford it, a laboratory glass washer),
- a water purifier (i.e. a still, de-ioniser or reverse osmosis unit),
- a refrigerator,
- a freezer (or combined fridge / freezer) and
- a drying cabinet (or oven).

In the diagram above, there should be flat bench space and room for 2 sinks. Equipment and materials used regularly for preparation can be stored above and below the bench. The height of benching should not be the same as in the laboratories, which are designed for students. In the preparation room, benches will need to be at adult height, i.e. 900 mm to avoid a technician having to stoop while working at the bench.

Washing-up area

The washing-up sink (to a depth of over 220 mm) should have a double-drainer and both hot and cold water. The hot water supply should be true hot water, not a blended or thermostatically-controlled supply. A dishwasher is almost essential and a drying cabinet would also be useful, although an oven might be used instead. A domestic dishwasher is satisfactory for most schools although using one in a prep room will invalidate its guarantee. A laboratory glass washer will give years of service but these cost between £1,800 and £3,200 depending on size, with, typically, £2,400 for generally suitable model. To the cost of purchase needs to be added the cost of installation which may not be the same as for a domestic dishwasher.

Office area

The office area for use by the technicians should include the following:

- a space for reading and writing,
- computer (with links to any local intranet and the internet),
- printer,
- telephone,
- storage for useful publications (e.g. *Hazcards,* suppliers catalogues) and currently used schemes of work,
- filing cabinets,
- lockers,
- a TV aerial socket (to record programmes).

7.4 Storage

Chemicals

A full discussion on chemical storage can be found in section 7 of the CLEAPSS *Laboratory Handbook*. If designers have questions about this rather specialised area of storage, they can contact CLEAPSS on the ***Helpline*** quoting the name of the school or local authority they are working for.

An indoor store is sufficient for most schools and colleges. By placing it so that is opens off the preparation room, security is enhanced and manual handling problems are reduced. An indoor store will require a fire-resistant cupboard to hold a maximum of 50 litres of highly flammable liquids, which will be sufficient for most schools.

Flammables cupboards must conform to data found in Appendix 2 of *The Storage Of Flammable Liquids*. Typical examples are shown on the right. Amongst the requirements are at least 30 minute fire integrity, class 0 surface spread of flame, fastenings that have a melting point greater than 750 °C and sufficiently durable that any spillages within the cabinet can be contained and removed without affecting fire resistance.

The following extract, relating to the ventilation of chemical stores, is taken from *Ventilation In School Buildings,* BB101, which states;

> *"Chemicals should preferably be stored in a dedicated chemical store room. As these are not occupied for significant lengths of time, a ventilation rate of 2 ach (air changes per hour) should suffice. Storerooms with well-sealed fire doors can preclude inward make-up air to replace exhausted air. This problem may also arise to a lesser extent with modern laboratories and prep rooms with highly sealed windows. Pathways for make-up air, and the location of intakes in relation to outlets, therefore need to be considered carefully. It is sometimes possible to fit grilles, even in fire doors."*

Chemical storerooms should have at least one outside wall.

The light switch for a chemical store should be located outside the room and the fan should be fitted with a time switch. Whether spark-proof electrical fittings should be used in chemical stores holding highly flammable chemicals is discussed more fully in section 7 of the *Laboratory Handbook.* However, If no dispensing is carried out, the risk of explosions is minimal and no spark-proofing is required. Even if a little dispensing were to be carried out, it can be argued that any release of vapour would never reach a level that could cause a problem.

It is not recommended that chemicals should be stored in the preparation room fume cupboard. However, a lockable cupboard placed underneath the fume cupboard and connected by a vent pipe can be used to store substances such as concentrated hydrochloric acid and bromine. It may be advisable to connect a time switch so that this cupboard is vented at regular intervals. Such an arrangement is especially useful if the school has no separate chemical store and these chemicals have to be kept in the preparation room where a technician is normally working for the whole day.

External chemical stores are often of prefabricated construction and such units are available with various degrees of fire resistance. Under the DSEAR, the following materials are deemed to be of minimal risk and do not require to be tested further: concrete, fired clay (brick), ceramics, steel, concrete blocks and plaster and masonry containing not more than 1% by weight or volume of organic material. Otherwise, if the building adjoins the school, the building material will need 60 minutes fire resistance.

Whether internal or external, flammable-liquid stores should be particularly carefully sited, account being taken of the need to:

- maintain escape routes in a fire,
- ensure that, in the interests of safe handling, dangerous chemicals should be kept as near as possible to the laboratories in which they are most likely to be used,
- prevent access by vandals, and
- shade from direct heating by the Sun.

Heating for frost and condensation protection is desirable in external stores (e.g. with a thermostat set to 10 °C) and the cost of this is one of the major arguments against an external site.

Windows should be avoided; they are not permitted on internal walls (i.e. walls common to a main building and an external store) and are not advisable for security reasons on external walls.

A single door is preferable unless the store is very large (for a school) in which case more exits may be required for fire safety. Doors should open outward and it should not be possible for somebody to be inadvertently locked inside the store. The entrance to the store should be ramped so that a trolley can be wheeled in.

Much is made of containment but the probability of catastrophic destruction of all containers in the store is extremely remote. If the free floor space is 3 m by 2 m and a full 25-litre drum suddenly leaks then the depth of the spill is less than 0.5 cm. If the floor slopes slightly to the centre then the spill will collect in an accessible place (not a drain) and can possibly be dealt with using the spill kit that is kept inside the store (staff should not put themselves at risk when dealing with the spill of a hazardous chemical).

There needs to be provision for a small store cupboard for radioactive sources. This should be in an area not permanently occupied by any one person but also not in the same room as the cupboard for highly flammables.

Small schools such as Pupil Referral Units, middle schools and prep schools

There may be so little room for storage in the prep room areas that the chemicals have to be stored in the laboratory where children work. In this case, all cupboards in the laboratories must be locked after use. In very small schools that have just one laboratory, no prep room and use a limited number of chemicals, this may be the only option. For these, there must be a small secure flammables cabinet, secure storage for corrosives and at least one other secure cupboard for the other chemicals. If storage is even more limited, the school can purchase diluted acids instead of preparing their own, thus doing away with the secure storage for corrosives.

Equipment

Also see Guide L248a, *Running a Prep Room*, section 6.2.

Commonly used equipment such as Bunsen burners, tripods, gauzes, heat-proof mats etc, along with basic eye protection, are best kept in the laboratories. Whether glassware should be kept in laboratories is a matter of departmental preference but technicians often complain that dirty and soiled glassware is left behind in laboratory storage cupboards after practical work. On the other hand, some approaches to science teaching require that pupils select the equipment they need from a range available.

If (some of) the laboratories and the preparation room are not on the same floor then more equipment, especially that which is heavy, may need to be stored out of the preparation room. For instance, microscopes, masses and rocks can be stored in specific laboratories to which pupils will come rather than the technician moving these heavy objects to separate laboratories on different floors. Having access to a hoist or lift between floors would help to address this problem.

Storage in the preparation room can either be static, mobile or rolling. Rolling storage, with the shelves moving on rails by turning a wheel, is particularly useful if space is at a premium. It is, however, expensive and upper floors may need to be designed, or reinforced, to be stronger than a standard floor. The shelving depth should be between 450 and 650 mm. A large array of removable tray storage can look impressive but will not be suitable for all the items needed to be stored. Shelves and/or cupboards are needed for large, long and bulky items.

Various tray racking systems are available with simple shelves, wire baskets or colourful plastic containers of various sizes that can be moved to a trolley quite easily. The trolleys supplied with such systems typically have small wheels and are unsuitable for carrying materials over rough surfaces.

Finally, if wall space is not a problem, consideration should be given to a suspended system where a track is fixed to the wall and shelving units, cupboards, panels and whiteboards are suspended from it.

Trolleys

Equipment trolleys are an essential item of the preparation room. Ideally, two trolleys should be provided per laboratory (plus one for the preparation room). This allows for one trolley to be in the laboratory (with delivered equipment) and the other in the preparation room (with returned materials and those awaiting delivery). They can be used for storage but more importantly they should be used by technicians for moving equipment from room to room instead of carrying it. Where equipment and materials need to be carried from one site to another across playgrounds etc, trolleys should have larger and more robust wheels.

Shelving

There is no reason why shelving, even in the chemical store, should not be made of wood. Steel and aluminium fixings do show signs of corrosion after a few years especially in the chemical store and should be inspected annually. There is no reason to have lips on shelves. Bottles have been broken by hitting the glass on the lip.

The height of shelving should not exceed 2000 mm. Light articles stored at this height should only be used on very rare occasions. Even so, stepladders will be required. Heavy objects (in excess of 10 kg), including piles of books and paper, should be stored between 800 and 1100 mm from the floor. See also section 7 of the CLEAPSS *Laboratory Handbook*.

7.5 The greenhouse and animal house

A greenhouse is a very valuable asset to a science department. It should be sited in a safe place because vandalism could be a problem. It could be bought from a local garden centre and erected by experienced workers who will probably have it built within a day. Further information can be found in section 14 of the CLEAPSS *Laboratory Handbook*. However, there are advantages in having a greenhouse that is an integral part of the building, e.g. adjacent to the preparation room. Not only is it convenient for technician use but also it is likely to be much less subject to vandalism.

Advice from the DfEE suggests that animals should be kept in a separate room to the preparation room. However, provision of a separate animal room is rarely justified nowadays. If animals are kept, and there are good reasons for doing so, particular attention will need to be paid to ventilation and variations in temperature.

Appendix 1 References

Government Publications

Asset Management Plans. Section 1 Framework, DfEE, 1999.	Available from DfEE Publications Centre, PO Box 5050, Sudbury, Suffolk CO10 6ZQ; tel 0845 602 2260; fax 0845 603 3360.
Building Bulletin 80: Science Accommodation in Secondary Schools. A Design Guide, School Building and Design Group, DfES, revised 2004.	www.teachernet.gov.uk/_doc/6152/BB%2080_19.pdf This is a very comprehensive and essential publication, particularly useful for suggested layouts, etc. Gives helpful guidance on costs, although the figures may become out of date as time goes by. CLEAPSS considers that there is too much emphasis placed on flexible or adaptable furniture and not enough on low-cost and easy maintenance.
Building Bulletin 87: Guidelines for Environmental Design in Schools, DfES, 2nd Edition 2003. School Building and Design Group.	This can be downloaded from www.teachernet.gov.uk/docbank/index.cfm?id=4753. This is a useful document as it provides useful advice based upon *The Education (School Premises) Regulations* 1999.
Building Bulletin 88: Fume Cupboards in Schools, DfEE Architects and Building Branch.	This publication can only be purchased through The Stationery Office at a cost of £14.95 (1998; £14.95; ISBN 0112710271), however a low resolution version with very low resolution images can be downloaded from http://publications.teachernet.gov.uk/default.aspx?PageFunction=productdetails&PageMode=publications&ProductId=0112710271& This is a revision of the previous publication, *Design Note 29, Fume Cupboards in Schools*, published in 1982 and based on research carried out by CLEAPSS. The DfEE commissioned CLEAPSS to write its successor, although there were subsequently some minor modifications. *Design Note 29* was the normal specification for school fume cupboards and its relevance to schools is acknowledged in the British Standard on fume cupboards. *Building Bulletin 88* does not significantly change the standard of *Design Note 29*, it merely expands on it and clarifies its meaning.
Building Bulletin 90: Lighting Design for Schools, DfEE Architects and Building Branch, 1997.	In section 5.3 it includes only a brief reference to science laboratories and preparation rooms. Amongst other things, it makes the point that good lighting helps avoid accidents. It suggests that bench tops should have a matt surface and be lighter in colour, although the latter may be vulnerable to chemical stains. www.teachernet.gov.uk/docbank/index.cfm?id=8413 The Stationery Office (TSO) ISBN: 0112710417. Price: £22.95.
Building Bulletin 93: Acoustic Design of Schools, DfES School Building and Design Group.	Published in 2003. Guidance is provided on controlling outside noise such as rain on the roof, aircraft and road noise, moving chairs from the room above etc. www.teachernet.gov.uk/management/resourcesfinanceandbuilding/schoolbuildings/environ/acoustics/
Building Bulletin 98: Area Guidelines for Schools, DfES, 2004.	Suggests 1 laboratory per 150 pupils as a rule of thumb. Gives further guidance on area when dealing with sixth forms. It uses a max of 30 pupils for each laboratory. www.teachernet.gov.uk/docbank/index.cfm?id=8104
Building Bulletin 100: Design for Fire Safety in Schools, DfES School Building and Design Group	ISBN 9781859462911 is available at £19.95 from RIBA Bookshops (Mail Order Office), 15 Bonhill Street, London, EC2P 2EA, UK; tel: 020 7256 7222 or it can downloaded from www.teachernet.gov.uk/docbank/index.cfm?id=12199.
Building Bulletin 101: Ventilation of School Buildings.	Published in 2006. BB101 discusses indoor air quality with examples of typical pollutants and how to control them in school buildings. It mentions school laboratories and prep rooms. www.teachernet.gov.uk/management/resourcesfinanceandbuilding/schoolbuildings/environ/iaq/

Building Bulletin 102: Designing for disabled children and children with special educational needs. Guidance for mainstream and special schools, DCSF, 2008.	Provides non-statutory design guidance on accommodation for children with SEN and disabilities for special school and mainstream school projects. Also available for download from www.teachernet.gov.uk/_doc/13210/BB102.pdf The Stationery Office (TSO) ISBN: 9780117039346 Price: £25.00
Central Point of Expertise on Timber Procurement's (CPET) (funded by DEFRA).	Go to www.proforest.net/cpet/
Contractors in Schools. Information for head teachers, school governors and bursars, HSE, 1996.	Available from HSE Books, PO Box 1999, Sudbury, Suffolk CO10 6FS; tel 01787 881165; fax 01787 313995.
Fire safety risk assessment: education premises.	Available from Department for Communities and Local Government Publications; tel: 0870 830 7099, ISBN 139781851128198 and ISBN 101851128190; and also available on www.firesafetyguides.communities.gov.uk,
Furniture and Equipment in Schools: a Purchasing Guide: Managing School Facilities, Guide 7.	This publication discusses specification issues although there is not a lot about science. www.teachernet.gov.uk/docbank/index.cfm?id=5641
Gas Safety (Installation and Use) Regulations. Approved Code of Practice and Guidance, L56, 1998.	HSE Books ISBN 0717616355
Manual Handling. Guidance on the Regulations, HSE Books, 1998.	Available from PO Box 1999, Sudbury, Suffolk CO10 6FS; tel 01787 881165; fax 01787 313995.
Northern Ireland. *Department* of *Education School Building Handbook* (Section 4)	Provides advice and guidance on the planning and design of new school buildings and the relevant standards. Should be used in conjunction with the Approved Schedule of Accommodation provided by the Department of Education. www.deni.gov.uk/index/85-schools/13-schools_estates_pg/ 13-content-buildinghandbook.htm
Northern Ireland. DENI circular No 2005/5	Provides guidance on permitted class sizes in practical subjects.
Project Faraday. *Exemplar designs for science.*	Project Faraday's main objective is to develop exemplar designs to inform and inspire all those involved in renewing or refurbishing their science facilities, particularly those involved in major capital programmes such as Building Schools for the Future (BSF) and Academies. It can either be purchased in paper form or downloaded from the teachernet web site. In paper: ISBN 9780112711971, TSO; tel: 0870 600 5522. Via the internet on www.teachernet.gov.uk/management/resourcesfinanceandbuilding/ schoolbuildings/innovativedesign/Faraday/
The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002	Available from www.opsi.gov.uk/si/si2002/20022776.htm. Schools are mentioned in DSEAR as a vulnerable audience.
The Education (School Premises) Regulations 1999, SI No 2.	This sets the basic legal requirements of the working conditions in a school. It says nothing about science laboratories. www.opsi.gov.uk/si/si1999/19990002.htm
The Storage Of Flammable Liquids HSG51.	HSE books ISBN 0717614719, although published under the previous Regulations, is still the basis of current advice.
Water Supply (Water Fittings) Regulations 1999, SI 1148.	Go to www.opsi.gov.uk/si/si1999/19991148.htm. These regulations do not apply to fittings in place before 1st July 1999.
Workplace (Health, Safety and Welfare Regulations) 1992. For glass in doors see *Approved Code of Practice*, Regulation 14 paragraphs 147 to 152.	Go to www.opsi.gov.uk/SI/si1992/Uksi_19923004_en_1. For a short, useful HSE information note on glazing see www.hse.gov.uk/pubns/indg212.htm.

Relevant CLEAPSS Publications

CLEAPSS *Laboratory Handbook.*	Many sections of the *Handbook* deal with aspects of laboratory design, either directly or by implication. Section 7 has details on the storage of chemicals which, on application, can be sent to architects or bursars as a separate entity. Section 8, *Laboratories*, is also relevant, although much of the chapter is concerned with maintenance and organisation rather than design.
L9: Fume Cupboards: Suppliers and Repairers.	Provides some advice on choosing fume cupboards but mainly information on suitable models for schools which meet the requirements of DfEE *Building Bulletin 88: Fume Cupboards in Schools*.
L77 Science for Secondary-aged Pupils with Special Educational Needs (January 2000).	Mainly about curriculum matters, but some references to adaptations needed.
L221 Developing and Using Environmental Areas in School Grounds (December 1998).	A lengthy guide that discusses the curriculum value of such areas, the facilities needed and issues of health, safety and maintenance.
PS9 Science Class Sizes, Laboratory Sizes and Possible Effects on Safety (2004).	The main emphasis is on class size and risk assessment, not on the design of laboratories.
PS24 Automatic dishwashers in school and college laboratories (March 2003).	Reports the results of a survey of schools that have used mostly domestic dishwashers in science preparation rooms.

Association for Science Education Publication

Laboratory design for teaching and learning, Association for Science Education, 2004.	www.ase.org.uk/ldtl/ This is a web site from which many useful documents can be downloaded. The case study information is interesting but the design programme is slow.
Topics in Safety, 3rd Edition, (2001).	Topic 6 is entitled Laboratory design for health and safety. It summarises some of the choices you have to make and also deals with chemical storage. Topic 7 is on fume cupboards.

Other Publications and resources

Publications by official bodes are very expensive with much detail and ‘in house’ jargon which the teachers and senior management will not understand without a lot of detailed study. They are not required to be bought by the schools but the school ought to expect that the architect and designer know about them.

BS 5482-1:2005, *Code of practice for domestic butane- and propane-gas-burning installations*.	This is for installations at permanent dwellings, residential park homes and commercial premises, with installation pipework sizes not exceeding DN 25 for steel and DN 28 for corrugated stainless steel or copper BSI. ISBN 0580447472.
BS EN 14056. *Laboratory furniture – Recommendations for design and installation.*	This is for the suppliers and installers. The space-distances between walls and benches and between benches is contained in this document. Available from British Standards Institution: Chiswick High Road, London W4 4AL; *tel:* 020 8996 9001; *fax:* 020 8996 7001; *e-mail:* info@bsi.org.uk; *web site:* www.bsi.org.uk.
Gas Installations for Educational Establishments.	IGE/UP/11, Communication number 1704, ISBN 0717700682. This provides information about the gas piping and gas cut-offs in school rooms, ISBN 0717700682, available from the International Institution of Gas Engineers, Chanwood Wing, Holywell Park, Ashby Road, Loughborough, LE11 3GH; email: general@igem.org.uk web site*:* www.igem.org.uk.
Guide to non-domestic gas pipework installation standards.	IGE/UP/2 Edition 2 – 2008, Communication number 1729. This document gives practical guidance to gas operatives when engaged in installing gas pipework used in the non-domestic sector. It provides guidance on flexible hoses.
LPGA Code of Practice 1: Bulk LPG Storage at Fixed Installations, 1998. *Code of Practice 7, Storage of full and empty LPG cylinders and cartridges*, LPG Association, 1998.	Publications available from The LP Gas Association, Unit 14, Bow Court, Fletchworth Gate, Burnsall Road, Coventry, CV5 6SP; email: mail@lpga.co.uk; web site: www.lpga.co.uk.
Requirements for Electrical Installations: IEE Wiring Regulations, BS7671:2008, ISBN: 9780863418440, £65.	This specialist document provides guidance for the electricians installing the wiring for the laboratory and protection from electric shock. See www.theiet.org/publishing/books/wir-reg/17th-edition.cfm.
SLL LIGHTING GUIDE 10: Daylighting and window design.	1999, ISBN: 0900953985**,** The Chartered Institution of Building Services Engineers (CIBSE).
The International Book of Wood, Edited by M Bramwell	Mitchell Beazley, 1976 ISBN-10: 0855330813; ISBN-13: 978-0855330811.
Timber Trades Federation.	An organisation which supports the sourcing and using of timber in the UK. Web site www.ttf.co.uk. For a list of suppliers of iroko use: www.ttf.co.uk/buying/products/products.asp?productid=23.
Wood Preservation. Author Barry A Richardson.	Taylor & Francis; 2 edition (4 Mar 1993) ISBN-10: 0419174907 ISBN-13: 978-0419174905.

Appendix 2 Model science suite / laboratory specification

The following is a model specification for a science department. It is based on documents supplied by several local authorities. It will need adapting to the needs of particular schools, especially if only one laboratory is to be provided, rather than a suite. Some situations will require compromises, especially where existing accommodation is to be adapted. However, the model specification will serve as a useful checklist to ensure nothing is forgotten. It also illustrates the level of detail needed to ensure that you obtain exactly what you want. Some parts are in square brackets indicating that the contents of the brackets may be additions or amendment. In one or two cases two such sections provide alternatives where one should be deleted. Where we thought it helpful we have offered suggested values but elsewhere the space between the bracket is left blank for the reader to insert appropriate numbers. This appendix needs to be read in conjunction with the main chapters of this guide and, in places, with other publications, particularly in Northern Ireland, with the DENI School Building Handbook.

Members can obtain a customisable version of this appendix (known as DL14) from the CD-ROM or the CLEAPSS web site.

General

1. The floor area of each laboratory should be 85 to 95 m^2.
2. All the laboratories on the same floor, serviced by a central preparation room and store. [If laboratories are not on the ground floor, then a service lift (hoist) should be provided.]
3. All laboratories should be general purpose, i.e. not specifically biology, chemistry, physics, although a few will have specialist facilities [e.g. blackout or one or more fume cupboard(s)].
4. A ducted fume cupboard to be provided in the preparation room. This fume cupboard needs have a corrosion-resistant, ventilated cupboard beneath it, for the storage of fuming or volatile chemicals.
5. Fume cupboards to be provided in 33 to 50% of the laboratories. In the teaching laboratories, fume cupboards should be glazed all round and sufficiently mobile that they can be pulled away from the wall for demonstration purposes. If there is a 6th form, one laboratory will require 2 or 3 fume cupboards, depending upon pupil numbers. Fume cupboards should not be located in corners, nor near doors where drafts might upset air flow. Guidance in *Building Bulletin 88* about siting and specification is to be followed.
6. Telephones should be provided both in the preparation room and in the science department office.
7. Access to the school computer network to be provided in all teaching laboratories, in the preparation room and in the science department office.
8. There should be good ventilation, with at least 6 air changes per hour in teaching laboratories and preparation rooms.
9. Window opening mechanisms should be easily reached, without having to climb on benches etc.
10. Floors should be level, with no steps and, if possible, no ramps. Floors to be covered with a durable material and, if appropriate, non-slip.
11. Very early in the design process a risk assessment is needed for each laboratory and prep room to determine whether a second exit is needed in case of fire.
12. A good general level of illumination is required, around 300 lux. In addition, where close or detailed work is carried out, e.g. in the preparation room, task lighting should be provided.
13. Furniture, and its purchase, should comply with the principles in *Furniture and Equipment in Schools: a Purchasing Guide: Managing School Facilities, Guide 7*.

Teaching laboratories

14. Each teaching laboratory should be sufficiently large to provide places for [30] pupils, working as [15] pairs; each pupil to have 0.36 m^2 work surface available. Each pupil also needs knee space and whilst a limited number of pupils may sit sideways to the teacher, no pupils should have their backs to the teacher. There also needs to be sufficient free bench space for setting out long-term investigations, laying out equipment to be selected by pupils, several computers / dataloggers and other items not on pupil work spaces.

15. Circulation spaces should allow distances between furniture in accordance with BS EN 14056:2003 or BB80: *Science Accommodation in Secondary Schools* (DCSF). There needs to be sufficient space for parking an equipment trolley and, if necessary, TV monitor + video / DVD player.

16. One double gas tap and one double electrical socket should be provided for each pair of pupils and one sink [size at least 300 × 200 × 150 mm deep] for each 3 pairs of pupils. Electricity sockets should be positioned to minimise risk of penetration by water. Service pipes, conduits and sink traps are to be protected by cupboards or false fronts, but ready access to sink traps is essential.

17. Each teaching laboratory should have one large sink [size at least 550 × 300 × 150 mm deep] with a supply of hot and cold water, through ordinary (i.e. not laboratory-type) taps, and grooved drainers. The hot water needs to be thermostatically controlled. Additional double gas taps and double electrical sockets should be provided on all peripheral benches, at intervals of approximately 2 metres. Gas taps should not be located under shelves, cupboards, display boards, etc where the careless use of Bunsen burners might present a fire risk.

18. Sinks should generally be of cast epoxy or fire clay. Drainpipes should be made of PVC or vulcathene. Each sink should be fitted with an anti-siphon bottle trap, in a position protected from interference by pupils but readily accessible for cleaning purposes. There needs to be an adequate number of access points for rodding.

19. Water taps should be about 300 mm above bench level (to allow tall containers to be filled or cleaned) and should be of a non-rotatable, epoxy-coated, pillar design. Anti-rotation devices should be fitted and detachable nozzles avoided. There are advantages in having two taps at teacher demonstration benches although the need for two separate, controllable supplies of cold water are infrequent. However, at the design stage, the cost is minimal and the additional facility removes a potential obstacle to some very useful demonstration experiments. Taps should be fitted sufficiently close to the sink for water to go easily into the sink. For ease of maintenance each tap or group of taps on a bench should have a service valve.

20. Electrical supplies to each laboratory should be protected by an earth-leakage circuit breaker, designed to trip at 30 mA in 30 ms. The cut-off for each laboratory should be adjacent to the teacher’s area, but not so close to the door used by pupils that they can misuse it easily. Power to any fume cupboards needs to be on a separate circuit along with two suitably marked double sockets (for use with aquaria, computers or by cleaners).

21. The gas supply should be capable of being turned off easily. A clearly labelled, mechanical cut-off for the gas supply should be positioned close to the point where the supply enters each laboratory. Alternatively a solenoid valve for the gas supply should be positioned close to the point where it enters each laboratory, with the push button adjacent to the teacher’s area, but not so close to the door used by pupils that they can misuse it easily. Gas taps must be of a sort that cannot be easily knocked open (i.e. pull-and-turn or drop-lever) and should be mounted such that they are easily visible by the teacher. Anti-rotation devices (e.g. Liverpool plates) should be fitted. [For ease of maintenance, each bench should have an isolating control].

22. Each laboratory needs a teacher’s area equipped with gas, water and electricity services, a white board for writing, an interactive whiteboard or screen for a projector, space, if necessary, for the projector and for a computer, work surface (with knee space) and lockable cupboard / drawers. Space may also need to be provided for a trolley with a large TV monitor and video / DVD. The teacher also requires some book shelves close by.

23. Full blackout is required in [some] laboratories (which should be ones which do not have a fume cupboard). Other laboratories require dim out only. This should be provided by roller blinds or slatted blinds, running in slots. Blinds must be non-flammable and should not interfere with ventilation arrangements. It must be possible to reach the operating mechanism easily, without having to climb on benches etc.

24. There should be provision for hanging coats and storing pupils’ bags for [30] pupils (fewer in Northern Ireland).

25. [Each laboratory should have a simple plumbed-in eye wash station] / [Where a sink is to be used for eye washing there should be a sufficiently large bench or table adjacent so that the casualty can lie on this, if necessary, whilst rinsing takes place. Taps should be positioned so as not to interfere with the irrigation process].

26. Furniture should comprise fixed benches around the walls, with […] tables / service pedestals / octagonal units, all at a height of 900 mm. Where pedestals / tables are used, distances between pedestals should be an exact multiple of the dimensions of the table, so that long runs can be created. Bench tops should be made of …, with a drip groove under the edges. In addition, there should be one adjustable height, fully serviced table (for use by those in wheel chairs).

27. Allowing for knee spaces, if required, and access to sinks, cupboards (with drawers / shelves / tray racks) should be fitted under fixed benches, with the cupboards mounted on plinths. There should also be […] wall-mounted, lockable, glass-fronted cupboards. There should be […] wall-mounted, (lockable) cupboards with wooden doors and […] book shelves. Except for sliding doors, all cupboard doors should be fitted with 270° hinges.

28. Large display boards should be fitted on walls not carrying cupboards, bookshelves or windows.

29. Each laboratory should have clearly labelled fire-fighting equipment as agreed with the fire officer – preferably two 2 kg carbon dioxide extinguishers and one fire blanket, to be located adjacent to the teacher’s base, but not adjacent to the door used by pupils.

30. Each laboratory should have […] (plastic-seated / wooden-seated / wood) stools for all pupils, the teacher and at least one visitor. Heights of stools shall be such as to leave a gap of 250 mm between the stool top and the underside of the bench.

Preparation and storage areas, etc

31. The total area of preparation room + store room(s) should be [0.4 to 0.5] m^2 for each pupil place provided (i.e. 15 m^2 for each 30-pupil laboratory; in Northern Ireland, 20 m^2). Of this, 25 to 30% should be work area, 20 to 30% fixed storage (including the chemical store), 10% mobile (trolley) storage and the remainder circulation space. The chemical store room door must be lockable and, if practicable, open directly off the preparation room. Other storerooms should at least be adjacent to the prep room.

32. Facilities in the prep room should include: a ducted fume cupboard, washing-up area with hot water and large sink [size at least 600 × 400 × 250 mm] made of […], a plumbed-in, domestic-type dishwasher, practical work area (adjacent to sink with water purifier [still / de-ioniser]), refrigerator, freezer [or combined fridge / freezer], gas and electricity services, parking space for trays of completed and/or returned preparations (could be on benches or on racking), space for parking at least 1 trolley per laboratory + 1, storage space for items for immediate use (e.g. tools), long-term storage space (depending on the provision of separate store rooms) and an office work area (with telephone, computer, book shelves, filing cabinet, place for personal effects). Some, or all, of the bench surface in the preparation area may need to be impervious if microbiological work is to be carried out there.

33. The chemical store should be ventilated with an extraction system fitted using an acid-resistant fan and operating on a time switch that can be over-ridden. If the chemical store is to be used for dispensing highly flammable liquids, switches should be outside the storeroom. The chemical store should contain a highly flammable liquids cupboard (capacity 50 litres), […] lockable wooden cupboards (for extra security), and shelves covering the remaining space. Shelving should be adjustable for height, mostly about 150 mm deep, but the bottom two rows should be about 200 mm deep. Along one wall there should be a plinth to store large bottles and a bund or sill to contain spills from them. (For an 11 - 18 school, approximately 44 m of chemical storage is needed, including any in cupboards or in the preparation room; 26 m is generally adequate for a school without a sixth form.)

34. The main storage should consist of a mixture of tray racks (compatible with the trolleys to be used), shelves and cupboards.

35. The teaching staff office should include work places for […] teachers, […] standard filing cabinets and […] computer work stations.

36. A greenhouse, with a floor area of approximately […] m^2 should be provided, if possible opening off, or adjacent to, the preparation room. If south-facing, it should have roller-blind shades and a means of (automatically) opening windows for use during summer months. It should be glazed on three sides or one side if it has roof glazing, with the glazing extending to floor level. Heating should operate independently of the school heating during winter months, and preferably be thermostatically controlled. If possible, fan heating should be provided since air circulation is desirable, otherwise tube heating should be provided. A piped water supply is desirable, with provision for a tap and connection to an automatic watering system, e.g. capillary matting reservoir tank. At least two waterproof electrical sockets should be provided. Standard 300 lux light fittings will be needed for staff, and additional lighting (11,000 to 21,500 lux) is desirable especially for successful plant growth in north-facing locations. There should be provision for suitable staging / benches for plant trays / propagators, permitting housing of plants to floor level if glazing is to this height.