Topic 6: laboratory design for health and safety

This *Topic* (dated November 2018) is an updated version of *Topic 6*, which appeared in the 3rd edition of *Topics in Safety* (ASE, 2001).

The updates are relatively minor, bringing the Topic up to date rather than reflecting any sea change in requirements for laboratories.

Introduction

This Topic is not intended to provide a blueprint for laboratory design. Further sources giving more detailed information on laboratory design are listed at the end of this Topic. The purpose of this Topic is to highlight some key health and safety issues facing anyone involved in the design of new or refurbished labs and to provide a briefing paper that the head of science can use in discussions with senior managers when dealing with safety issues involving the design of science facilities. Sadly, it is all too often the case that science departments, and indeed schools, are often presented with a *fait accompli* at the last minute but a more enlightened approach is sometimes to be found where those who will actually be using the facilities will have an input into its design, be that an update of existing facilities or a complete new build. This Topic aims to be helpful in both cases and also should be of use to heads of science managing existing facilities and trying to keep the health and safety provision as up-to-date as possible.

6.1 Strategic design for health and safety

6.1.1 Position

A high proportion of accidents in school science are traffic accidents, which fall into two broad categories.

- Technicians transporting materials or equipment over long distances or on difficult journeys which might involve a change of level or movement from one floor to another.
- Collision between technician and students using the same thoroughfares.

The ideal solutions to these hazards involve careful initial design. Storerooms and prep rooms need to be centrally located so that distances between them and the laboratories they serve are minimised. Ideally technicians and students should use separate traffic routes, but this is unlikely to be practicable in most cases so the transport should be managed to avoid periods of busy traffic.

There is much to be said for science departments occupying a single floor but this is clearly impractical for larger departments and indeed in many schools.

The choice of floor can be important: from the point of view of ventilation, it is much easier if chemistry labs and preparation areas are on the top floor but this may cause difficulties with transportation of equipment.

Departments occupying two or more floors should have a prep room for each floor and an excellent lift system designed to accommodate trolleys and technicians. In this case the head of science will need to devise methods for dealing with the loss of flexibility caused by the restrictions in movement. Where apparatus, chemicals and equipment are moved using trolleys, movement should be minimised and if possible there should be designated trolley parks. One solution involves the storage of trolleys at both ends of their journey and the provision for this should be considered at the design stage.

The provision for deliveries should be considered in the overall design of the department. When hazardous materials or delicate equipment arrives, it should be transferred as quickly as possible to safe storage and not left, for instance, in the school foyer.

6.1.2 Fire Safety

Modern buildings will meet current fire regulations. The laboratories and prep rooms must have two exits 'if a single exit door would be in a hazardous position'. The final decision as to the necessity of a second exit will be determined by a fire risk assessment, 'In general there should normally be at least two escape routes from all parts of the premises but a single escape route may be acceptable in some circumstances (e.g. part of your premises accommodating less than 60 people or where the travel distances are limited).[1] The decision about this will probably need expert advice.

It is preferable to have exits leading directly to corridors etc. but an exit into another laboratory can be acceptable provided the laboratories are properly separated. Again, this will be determined by the fire risk assessment.

Stairwells should be isolated from the corridors by fire doors. An important feature of fire doors is how you push or hold them open to wheel a trolley through. You should not have to wedge them open but there are various hold-open devices which are automatically released, eg by the sound of a fire alarm complying with the British Standard.

These are minimum requirements and thought should also be given to escape routes used in emergencies and factors such as the effect of door and corridor width on the speed and ease of a full evacuation. Older buildings may have laboratories which share a ceiling or roof void. Fire can spread with great speed across such voids and any upgrade should include consideration of the possibility of installing firebreaks.

6.1.3 Security

Security is an important aspect of design. The designer needs to consider the protection of the building from outside intrusion in terms both of the quality of doors, windows and locks and of eliminating blind spots where illegal entry may be unseen.

Outside stores are more vulnerable than stores inside the building and should be avoided where possible.

It is common for schools to lock entrance to the science block eg at lunch time. This gives clear corridors for technicians to move trolleys around and to leave lab doors unlocked but may delay access if the technician is involved in an accident.

Careful siting of vulnerable rooms such as stores and prep rooms may also reduce the possibility of casual theft or vandalism. Unauthorised access needs to be difficult and supervision easy. It must be borne in mind that good design alone will not protect a building and appropriate management of the facilities is also essential. In particular, careful consideration should be given to who has keys to the more hazardous areas such as the chemical store. There is a clear directive from the Home Office, *Secure Your Chemicals*[2], which emphasises the importance of controlling access to hazardous substances.

6.2 Laboratories and prep rooms

One of the main considerations in the design of laboratories and prep rooms is the extent to which they are to be specialist facilities or will cater for all sciences and all age groups. Laboratories used for chemistry experiments require the greatest additional investment for health and safety (laboratory ventilation, fume cupboards and services (gas and water). The counsel of perfection is to design for maximum flexibility but the decision will depend on both philosophy and finance.

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[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/14887/fsra-educational-premises.pdf

[2] The document is no longer available on any government website but copies can be obtained from CLEAPSS and SSERC

A lab used for A-level chemistry (or equivalent) needs 2 or 3 fume cupboards. Labs used up to GCSE (or equivalent) for chemistry need 1 fume cupboard, so about a third of laboratories need 1 or more fume cupboards. Mobile fume cupboards are often proposed as the answer (whether filter or ducted) but they are not: evidence shows that they are rarely moved as it is too demanding on technician time to uncouple the services, move stools out of the way, get a second technician to hold the door open, wheel the cupboard along the corridor when free of children, hold the next door open, etc.

6.2.1 Laboratory size

The size of the laboratory will depend on the numbers in the largest groups to use it. There are significant differences across the UK:

- In Scotland practical class sizes are limited to twenty students.
- In Northern Ireland it is a little more complex: 20 is a general figure but the number can be higher, exactly how high is determined by the age of the pupils, the size of the laboratory and the nature of the activity.
- In England and Wales it would seem realistic to expect a maximum class size of thirty (or possibly thirty-two).

The UK government recommendation[3] is for such a laboratory (in England and Wales) to have a floor area of 83 - 90 m^2. In Scotland and Northern Ireland, the size should be of a similar proportion for the numbers involved.

If the laboratory is too small, overcrowding will result. This can have various implications for health and safety in an emergency, for instance, are pupils so crowded that the teacher cannot get across the room? Can pupils heat a test tube, for example, without pointing it at themselves or others?

Floor area is only one guide; the proportions of the space are significant and a laboratory also needs to be furnished, which can reduce the available area. For the most efficient general supervision of practical work the laboratory should approximate to a square (BB80[4] recommended a 10:8 ratio).

6.2.2 Ventilation

Laboratories and prep rooms need good ventilation and it is desirable to have 5-6 air changes an hour. Opening windows will provide basic ventilation but many modern buildings are built with windows that cannot be opened. In some designs air is re-circulated which can spread smells throughout the department – or whole school. This is not a satisfactory system for a science lab and even less so for a prep room: the spreading of smells is a minor annoyance but the same system would also allow for the spread of toxic gases in case of a spill. Another problem can be caused by ventilation systems which push fresh air into the room rather and extracting: this can create a positive pressure which can, in some circumstances, push harmful fumes into other areas.

In addition, laboratories used for chemistry should be fitted with extractor fans for which air inlets will also be necessary. These should be under manual control so that a boost to the natural ventilation can be applied when circumstances require it. Air inlets need to be placed to provide a proper flow of air through the laboratory. Fume cupboards ideally need to be sited away from corners and doors where turbulence might affect their performance. Fume cupboards and extractor fans should be on a separate circuit from the other sockets to minimise the possibility of nuisance

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[3] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/324056/BB103_Area_Guidelines_for_Mainstream_Schools_CORRECTED_25_06_14.pdf

[4] http://science.cleapss.org.uk/Resource/Building-Bulletin-80.pdf (Now out of print but still contains much useful information – available from the CLEAPSS and SSERC websites)

tripping of RCDs disabling them and creating a risk to health and safety. Remember that different ventilation systems affect each other and also the response of a room to fire. Furthermore, extraction systems generate noise which can affect class control. 'A noisy fume cupboard is hazardous. Students working at a cupboard, or watching a demonstration taking place in one, need to be able to hear the teacher. If a cupboard is too noisy, there will be a strong temptation to switch it off or students may mis-hear instructions'[5].

6.2.3 Lighting

Laboratory and prep room lighting is difficult. It goes without saying that teaching areas need to be well lit and that natural lighting has obvious benefits. However, thought needs to be given to the negative effects of bright sunlight. These include rendering Bunsen burner flames invisible, dazzling students and making rooms uncomfortably hot. Fitting solar film to the glass can significantly reduce these effects but this of course reduces the light levels in the room, a particular problem if plants are grown on window sills. There is frequently a need to dim a laboratory which can be achieved using curtains, or fabric, plastic or metal blinds. Curtains are significantly less safe than the other options, particularly in chemistry laboratories.

6.2.4 Utilities

All laboratories and prep rooms need gas, water and electricity and each room should have separate isolation valves or switches for each of the services. The electricity supplies should be fitted with a residual current device which can double as an isolation switch. Some consideration needs to be given to the positioning of these isolation devices. One possibility is to site them just inside the main exit door to the room but there is also much to be said for placing them by the teacher's bench. Gas regulations require a gas shut-off where the supply enters the room but this may not be ideally placed for use by the teacher in an emergency. Use of a solenoid valve allows the switch to be located anywhere convenient. Washing and eye-wash facilities are essential for all laboratories (see Topic 5).

Thought also needs to be given to the positioning of the outlets within the room. Bunsen burners, for instance are better not adjacent to opening windows where they can get blown out. A common problem in new buildings is positioning utilities in such a way as to make some practical work more difficult: for instance having gas taps on pods in the middle of the room and water around the perimeters – thus preventing distillation without using heating mantles.

Water supplies are becoming particularly problematic. In order to comply with the Backflow Regulations, some schools have their laboratory and prep-room taps fitted with interruptor devices. This is the cheapest option but is not suitable for use in science facilities. They do indeed prevent backflow but they also prevent sufficient pressure being produced to allow for vacuum filtration and even use of a condenser/reflux apparatus. The only suitable option is for the science department to have its water supplied via a separate header tank where suitable control to prevent backflow can easily be achieved.

6.2.5 Alarms

If smoke alarms are fitted it is important that they are automatically switched off when laboratories are in use, as they will be triggered by many class activities involving heating. Heat sensors are a much better option for laboratories as smoke can be generated by a variety of junior science experiments which will not always be carried out in a dedicated chemistry laboratory.

There is a growing trend to fit carbon dioxide alarms in laboratories. If these are linked to enhanced ventilation (or alert the teacher to the need for this) then all is well and good but many chemical

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[5] http://science.cleapss.org.uk/Resource/G9-Fume-Cupboards-in-Schools.pdf (An updated replacement for the DfE Building Bulletin 88 – Fume Cupboards in Schools)

procedures will greatly raise the level of CO_2 in the room and an alarm that simply alerts but allows no action is of no practical use.

6.2.6 Laboratory furniture

Many new laboratories built have a common design feature using peripheral benching carrying the services of gas, water, drainage and electricity and with loose tables and chairs in the central area. This layout is cheaper to build. Such designs have implications for the quality of teaching and learning and especially for health and safety, and for the way in which risk assessments can be used[6].

The choice between fixed benching and flexible units has been extensively discussed and debated.

Problems can arise when the flexibility is used to create a configuration which affects the emergency escape routes within a room or access to emergency equipment such as eye-wash facilities or fire extinguishers. The conventional fixed system needs, of course, to have an optimum configuration for supervision and escape which needs to be established at the design stage. Long runs of benches that split the room and awkward corners without easy local escape routes should be avoided. The position of the board is an important decision. This is frequently on a short wall although the longer wall brings the class closer on average to the teacher and should improve supervision.

The design of the laboratory or the provision of its furniture should allow for the neat storage of bags. Clearly these should not obstruct gangways or escape routes directly or, indeed, indirectly by preventing stools being stowed under benches. Possible solutions will include additional under-bench storage or shelving; an alcove is a useful design feature. Here and elsewhere good management of the laboratories is as important as good design and such storage must not become a receptacle for waste. Additional planned storage for goggles and for laboratory coats (if used) is also desirable.

There is a wide range of materials suitable for floor coverings and benches. Floors need to be hard-wearing, suitably non-slip (so as not to abrade the ferrules on the bottom of stools), chemical resistant and easily cleaned or disinfected. From the safety angle there is perhaps little to choose between the various alternative materials for floors or benches.

6.3 Storage

To a large extent storage will depend on the layout of the school. Modern designs have a central store and an adjacent prep room area but in existing buildings compromise is inevitable. Any store needs to be readily accessible to technicians (and possibly other staff) and inaccessible to students and unauthorised personnel. There should be additional, possibly separate, secure storage for expensive equipment. Outside stores should be avoided if possible, as such stores are susceptible to vandalism, labels rapidly become unreadable and they often lead to the creation of unofficial internal stores, to avoid journeys outside in bad weather.

Lighting should be excellent to reduce the possibility of error. Storage on deep shelves should be avoided, as should placing heavy equipment or bottles above eye level. Some stores may need provision for securing gas cylinders either on or off their trolleys.

6.3.1 Chemical storage

There should be a separate chemical store, preferably opening off the prep room area. It needs good security (a requirement of the Home Office directive *Secure Your Chemicals*) and it is desirable though not essential that doors should open outwards. Ventilation can be achieved using air-bricks at a high and low level if there is an outside wall; otherwise, extractor fans on a time

[6] http://www.ase.org.uk/journals/education-in-science/2007/04/222/

switch, or running constantly, will be necessary. In either case, bottles, trays, cupboards etc should not be placed in front of the vents.

Ideally, the floor should slope away from the door and be made of concrete or quarry tiles. The chemical store should have a spillage kit. If at all possible, dispensing should not take place in the chemical store. Running water may be helpful in emergencies unless the store is adjacent to the prep room but it should not have a gas supply.

Spark-proof electrical fittings (e.g. fans and lighting) are not essential unless highly flammable liquids will be dispensed there. Even then, such provision may not be necessary if there is good ventilation and dispensing takes place some distance (e.g. 2 m) from any electrical fittings. If there is any dispensing happening in the store, a risk assessment should be carried out to ensure that spark-proof fittings are not actually required. With new buildings and refurbishment it is usually easy to locate switches outside the store and this is preferable.

Highly flammable liquids can be stored within the chemical store in flammables cabinets, with a maximum of 50 litres in any one room. Other chemicals can be arranged on shelves in the locked chemical store but, if local conditions suggest that extra security is required, they can be locked in ordinary wooden cupboards.

Chemicals can be separated into:

- flammable solids and liquids
- corrosives
- oxidising agents
- inorganic chemicals*
- organic chemicals (non-flammable)*
- large bottles of made-up solutions.

* it may be preferred to combine organic and inorganic chemicals. As long as incompatible substances are kept apart, it is a matter of preference.

It is rarely useful to have a separate poisons cabinet. Indeed, such a cabinet can result in incompatible substances being stored close together simply because they are poisonous. There may be an argument for one in the case of a school without a dedicated chemical store but any school without such a provision would be well advised to avoid the use of highly toxic substances in the first place.

- Incompatible chemicals (e.g. acids and alkalis or oxidising agents and most organic chemicals) should be stored as far apart as practicable, e.g. in different cupboards, or on shelves on different walls of the store room.
- Large bottles should be low down but off the floor, or protected from kicking. This can be achieved by standing them in a container such as a plastic trough or on a plinth. In the latter case further protection can be achieved by using a barge board to retain an absorbent material such as sand.
- Chemicals that are decomposed by water in the atmosphere, such as silicon IV chloride or calcium carbide, should be kept in containers with soda lime.
- After use, bottle necks and drips should be wiped to avoid any further evaporation within the store. Ensure caps are firmly screwed on.

Effective storage requires good management of resources with equipment and materials organised in a simple but effective way that allows for rapid stock checks and easy removal of out-of-date chemicals or other materials. A possible organisation of a chemical store is illustrated in Appendix 1. Appendix 2 summarises the main options for the storage of chemicals.

If, exceptionally, there is no alternative, the design of the school may dictate that chemicals have to be stored in the prep room. This may just about be acceptable if the project is a renovation of a situation that does not at the moment have a dedicated chemical store but there is no justification for it in a new build.

In this case all but the most innocuous should be locked away to prevent the possibility of theft or accident if students enter the room. A school in this situation should also review its stock of chemicals and consider adjusting the nature of the practical work if need be to avoid the use of the more hazardous substances. As chemicals will be dispensed, access to a fume cupboard will be necessary in the prep room. This should be of a ducted design to cope with the larger quantities and concentrations of chemicals used by technicians. In addition, forced ventilation (with an extractor fan) is almost certain to be necessary.

6.3.2 Radioactive storage

Radioactive substances should not be kept within the chemical store if at all possible, though if there is nowhere else suitable, it may be acceptable.

They should be kept in a suitable receptacle in a secure place but they must not be within 2-3 m of any area occupied by the same person on a regular basis, such as a washing-up sink or technician's desk. This includes areas on the other side of walls.

6.3.3 Biology stores

A biology store may well need a refrigerator for microbiological materials but highly flammable liquids must not generally be stored in or adjacent to it.

However, there are occasions where biological work calls for very cold ethanol or propanone. In this case, the smallest quantities needed of the solvent should be stored in small, tightly-capped bottles which are themselves inside another sealed container.

Ideally chemicals used in biology work will be kept in the main chemical store but if this is impractical then the same precautions for safe storage should be observed as described above.

Further information

The Lab Design page on the ASE website (http://www.ase.org.uk/resources/lab-design/) contains links to a variety of useful resources including:

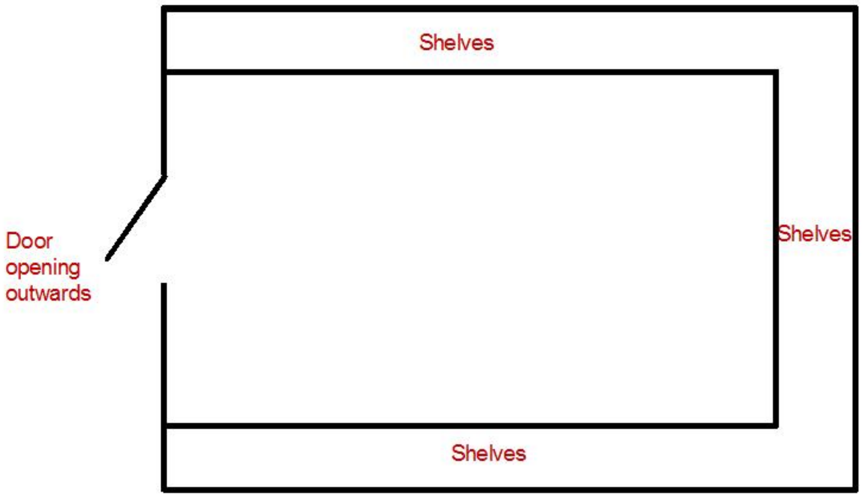
- Safeguards in the school laboratory, ASE (11th Edition 2006). ISBN 978-0-86357-408-5. Available from the ASE bookshop (https://www.ase.org.uk/bookshop/safeguards-in-school-laboratory-11th-edition)
- Guide G14, Designing and Planning Laboratories, CLEAPSS (2009) (http://science.cleapss.org.uk/Resource/G014-Designing-and-Planning-Laboratories.pdf)
- Building Bulletin 80 - Science accommodation in secondary schools, a Design Guide (Now out of print but still a very useful document) Available from CLEAPSS and SSERC (http://science.cleapss.org.uk/Resource/Building-Bulletin-80.pdf)
- Laboratory design: a guide for schools and colleges in Scotland, SSERC(2014), (https://www.sserc.org.uk/wp-content/uploads/2018/11/Laboratory_Design_2018.pdf)

Appendix 1: Possible organisation of a chemical store

The diagram below shows possible arrangements for chemical storage.

The tables show possible contents for shelves on the wall each table is adjacent to.

Top	Inorganics (in alphabetical order)
	Inorganics (in alphabetical order)
	Volatile corrosives
	Sets of acids & alkalis / Spill kits
Bottom	Bulk acids & alkalis



Top	Inorganics (continued)
	Inorganics (continued)
	Water reactives (in containers)
	Solutions
Bottom	Large containers (inorganics)

Top	Organics (in alphabetical order)
	Organics (in alphabetical order)
	Organics (in alphabetical order)
	Organics (in alphabetical order)
Bottom	Large Containers

Appendix 2 Options for storing chemicals

Category	Code	Group	First option	Second option	Third option	Keep away from
Flammable substances	FL	Liquids	Fire-resistant cupboard in chemical store or prep room	External store meeting fire requirements	Strict limits on stock	GO, T
	FS	Solids	Internal chemical	Internal chemical	Locked cupboard	GO, CL, FL
	FM	Water reactives	Store in locked cupboard	Store on shelves away from GO	In prep room or store	
Toxic substances	T	Toxic chemicals	Internal chemical store always locked or in locked cupboard	Locked cupboard in prep room or store	Locked cupboard in laboratory	FL
Corrosive substances	CLa CLb	Liquids, acid Liquids, non-acid	Internal chemical store at low level in waterproof storage well	Prep room or store at low level	Laboratory in low, locked cupboard	CLb, FM, T CLa, FM, T
	CR	Volatiles	Exclusive cupboard, with ventilation to outside, located in chemical store	Dry cabinet, desiccator or plastic box with desiccant and soda lime	Internal store near ventilation	FM
	CS	Solids	Internal chemical store with general chemicals	Prep room or store in cupboard	Laboratory in locked cupboard	
General chemicals	GO	Oxidising	Internal chemical store with inorganic chemicals	Prep room or store with inorganic chemicals	Laboratory in locked cupboard	FL, FS, FM, GC, CL
	GI	Other inorganics	Internal store	Prep room or store	Laboratory in cupboard	
	GC	Other organics	Internal store	Prep room or store	Laboratory in cupboard	
Special cases	S	Bromine	With corrosive, volatile chemicals (anhydrous Na_2CO_3 and 1 M $Na_2S_2O_3$ to hand)			FM
		Methanal	Secure biology storage or with toxic chemicals			CL, CR
		White phosphorus	In water in locked cupboard in store or prep room, maybe with toxic chemicals			GO, FM
		Silicon tetrachloride	In dry container, cabinet or desiccator with silica gel			
		Sulfur dioxide	Cylinders should be stored on an open shelf in a ventilated store			CR, CL
		Gas cylinders	Fixed either to bench or trolley			FL
		Radioactives	Special cupboard (site with care)			FL, CL