GUIDELINES for the design and planning of secondary school science facilities in Australian schools

Acknowledgements

These guidelines were produced by the Science ASSIST project managed by the Australian Science Teachers Association (ASTA) in consultation with the Science Education Technicians Association (SETA). The Science ASSIST project is supported by the Australian Government Department of Education and Training through the Mathematics and Science Participation Program.

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1 Introduction

Secondary school science facilities comprise science teaching laboratories, preparation and storage areas as well as dedicated office space for science teachers and technicians. Schools that wish to build new facilities or refurbish existing rooms often ask what the requirements are for school science facilities. Most staff in schools are not experienced in laboratory design and would like to have access to the latest guidance information regarding good practice and design.

There have been no nationally established guidelines for the design of school science areas, and whilst different education jurisdictions may have their own brief, many schools engage architects who may or may not have had experience in the design of school science facilities.

Australian Standards have standards for laboratories in general (research and commercial) but are not specific to school science laboratory requirements[1].

Schools also have a range of factors that need to be taken into consideration over and above regular laboratories. For example, if class sizes are up to thirty-two students and they need to be evacuated from a room in the event of an emergency, whilst only one doorway might be required in the Australian Standards, a risk assessment might determine that two doors are required. Student behaviour also needs to be taken into consideration with regard to the type and quality of furniture and fittings to minimise potential vandalism. With the growing trend of using computer based technologies, future planning to facilitate this needs to be considered.

Since starting in 2013, the Science ASSIST advisory service has received numerous requests for information on school laboratory facilities and design. In response to this demand, it was decided to produce a set of guidelines for the design and planning of secondary school science facilities for use by Australian schools.

CLEAPSS is an advisory service providing support in science in the United Kingdom, which produced a guide in 2009 called *G14 Designing and planning laboratories*.[2] This guide addresses most aspects of the school science area. It was written for schools in the United Kingdom and complies with their building regulations. With CLEAPSS permission, Science ASSIST has used this guide as a starting point for the development of a resource for Australian schools with references to the relevant jurisdiction building codes, Australian Standards, risk assessment and risk management systems, best health and safety practices, and technology and curriculum requirements, particularly those of the Australian Curriculum: Science.

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[1] Note: Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982: 2010 Laboratory Design and Construction*, Standards Australia: Sydney does contain a small section with some additional notes and requirements for secondary school laboratories.

[2] CLEAPSS. 2009. *G14 Designing and Planning Laboratories*, Association for Science Education (UK) website, http://www.ase.org.uk/documents/lab-design-designing-and-planning-laboratories/

2 The project brief

2.1 Determine the scope and limitations

The first step in the planning and design process must be to determine the number and type of rooms required and to decide how the facility will be used.

Sufficient laboratories are required to teach practical science and allow time for proper routine servicing and sensible timetabling. The optimum situation, although not always possible, is to have all science lessons capable of being conducted in multipurpose teaching laboratories.

A straightforward way to determine this is to:

- 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 80–90% occupancy for sensible timetabling. Round to the nearest whole number.

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

It is wise to factor in flexibility into the design of the rooms so that size-wise they can all cater for a full number of students and that overall there is capacity to enable a wide range of courses to be conducted. For example, rooms may need:

- sufficient fume cupboards to teach chemistry.
- sufficient black out to teach physics.
- compliance with Physical Containment (PC) level 1 to teach microbiology[3].

Also for consideration is the:

- areas of the Australian Curriculum: Science to be taught in the facility, e.g. the year levels, science subjects, and other resources such as storerooms, staff offices, preparation laboratories.
- flexibility needed in the functions that each area provides, e.g. teaching laboratories dedicated to a specific subject such as senior physics or chemistry or more general use across other curriculum areas?
- number of classes, students and staff members that will be accommodated.
- provision for expansion during the life of the facility.
- fittings, fixtures, equipment and materials required, and the hazards that they may bring.
- management of the risks specific to science operations.

2.1.1 The cost

Whether newly built or renovated, school science laboratories are expensive investments that are expected to last for many years. The success of the investment

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[3] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS2243.3: 2010 Safety in laboratories Part 3 Microbiological safety and containment*. Standards Australia: Sydney, Section 5.2 p.38

depends on the value obtained for the money outlaid. A cheaper option in construction may not be the best investment. When deciding what is affordable, any assessment of the cost over the life of the facility must balance the initial capital expenditure against recurrent costs of repairs and maintenance.

2.1.2 The duration

Notwithstanding the project timelines and some hard deadlines that must be met, the construction of an entirely new science facility—even within an operational school site—could go ahead without significant disruption to the science-teaching program or other school operations.

This is not the case when the project involves renovation, refitting or extending existing science accommodations that are in use. Such a project must be managed to minimise disruption to classes and general school operations.

In either case, construction work may require access to the site for heavy vehicles, delivery and storage of construction materials and equipment and inevitable interruptions to power, water and other services. Even relatively superficial maintenance such as repainting of walls and renewal of floor coverings or bench tops will need rooms to be vacated for a time.

Most schools will try to schedule the work during school holidays and plan for the completion and commissioning of the new facilities to coincide with the beginning of a school year, term or similar convenient break in a school's academic program.

In Australia, term holidays during the school year are typically only two or three weeks long. The end-of-year break is longer; 5–8 weeks depending on the jurisdiction but this includes the national Christmas and New Year closure period for many companies and building contractors. In Australian northern regions it is also the 'wet' season when building operations will be affected by extreme weather events.

For anything other than very minor renovations the duration of the work and the time required for packing up and unpacking is likely to exceed the length of the term holidays or other periods when the science laboratories are not in use. It will be necessary to find alternative accommodation for science classes, or conduct the renovation work in stages. Both will have significant effects on delivery of the science curriculum and the technical services that support it.

2.1.3 The stakeholders

The stakeholders comprise those who will use or maintain the new facility, those who are affected during the process of construction, and the various contractors engaged to undertake the work. All must be included in the overall planning of the project. The overall success of the project depends on effective consultation from the beginning with all these groups.

Each group will have their own expectations of the project and the final product. Each must be considered but no single individual should have his or her own way if it overrides the needs of the others or the functionality of the science facility.

Highly idiosyncratic ideas for design and fit out of the science facility, whether traditional or innovative, may not be practicable but once installed they must be tolerated over the life of the building. Rather than following extreme requirements of a single individual, the design team should find a compromise that will satisfy most of the stakeholders, and of those who will use the facility in the future.

2.1.3.1 Teachers

Teachers, whose teaching laboratories and offices are being built new or renovated, will know how they expect to deliver the Australian Curriculum: Science. The curriculum must drive the planning and design process. Well-designed science areas that can accommodate all forms of teaching will facilitate sound delivery of the curriculum. These include good physical location within the school and with good communication systems (such as office/s close to the science area, technician/s office and preparation room); ease of use; flexible reconfigurable space to suit curriculum needs; accessible storage space and display areas for student work.

2.1.3.2 Laboratory staff

Experienced science laboratory technicians have a unique perspective on the requirements of the entire science precinct, not only the teaching laboratories and preparation laboratory. They are well placed to understand how all the elements of a science precinct must interact for a successful science program.

Technicians not only prepare and distribute materials and equipment for practical classes but they also consult with teachers about class programs and materials, and liaise with the school department that manages repairs and maintenance. They understand how the facilities' overall design and capacity affect all aspects of the science program. They also observe the performance of the various fixtures and fittings under their usual operating conditions.

2.1.3.3 Students

The quality of the learning environment will have an effect on students' experience. Students will not value teaching laboratories that are poorly designed or inadequately resourced for practical work.

Fittings and fixtures that are not sufficiently robust to withstand student use will quickly degrade and become the target of vandalism and further damage.

2.1.3.4 Other staff members and visitors

The position, design features and construction of a new science facility may have an impact on other areas of the school. Those people affected should be included in the early consultation phase so that any negative impact is minimised.

During the construction period there may be disruption to other classes and outdoor play areas. Access routes within and between buildings may be altered or limited and power and other utilities may be interrupted.

2.1.3.5 The wider community

The impact of the construction of a new school facility on the surrounding streets and the local community should be considered.

- The visual effect on the streetscape.
- Ambient light and reflections onto surrounding homes and gardens. When an entirely new building is proposed these matters are likely to be considered when the permit application is lodged with the local government authority. In the case of a refit of an existing facility something that is considered a minor addition such as a new window or wall can adversely affect a near neighbour if it adds unwanted glare or reduction of light.
- The environmental effect of the science facility and its operations such as hazardous chemical storage and disposal, generation of hazardous fumes, noise.

- Access for emergency services such as fire services and ambulance.
- Disruption to power, gas, water and waste utilities during construction.
- Traffic disruption and access for heavy vehicles and machinery such as cranes.

2.1.3.6 The architects and builders

It is the senior administrators of the school's governing body or State education department who have responsibility for negotiating with the architects and building contractors over the design brief of a school science facility.

Architects are often blamed for features of new science buildings and renovations that don't measure up to the expectations of the stakeholders either in the design or in the content or quality of the construction. Architects, designers and builders who have experience with schools projects may not have been involved specifically in planning secondary school science laboratories.

The outcome can only be as good as the consultation during the development of the design brief. If the school administrators do not encourage consultation with the other stakeholders before and during construction then some of those groups may be unhappy with the result.

While it is not practicable for each of the stakeholders to meet with the contractors individually, there must be opportunity provided for the groups to consult from the very beginning of the planning stage through to the final design drafts.

2.2 Management of risk: Hazard identification and risk control

Science facilities have hazards that are inherent to their function and operation.

The design of the new science facility must include management of known risks. These are quite separate to the hazards present during the construction of a new building or renovation of existing facilities.

2.2.1 Working in the area during construction.

Building a new science wing within an existing school or a renovating an existing building brings a range of risks to be controlled. Effective management of the following risks will minimise disruption and delays to the project:

- Heavy vehicles and machinery
  - Earth-moving, cranes, delivery of building materials and hazardous substances.
  - Additional vehicle traffic within the school precinct
- Noise, dust, fumes or sparks generated by construction or demolition processes that may create risks to health and damage to equipment and fittings.
- Interruption to essential services: water, gas, electricity, which is not merely inconvenient but also a safety hazard.
- Reduced access for school personnel within and between school areas.
- Additional persons on-site who may not be authorised to interact with school staff and students.
- Emergency incidents related to the construction processes; e.g. fires, personal injury, or collapse of buildings under construction or demolition.

Elimination of all risk to school personnel and operations is not practicable but there are measures that will provide some degree of risk control.

- Construction areas should be isolated from occupied areas of the school. If dust is being generated through construction activity, the area should be sealed to prevent the dust dispersing to the occupied parts of the building. Equipment should be either covered to protect from dust or be relocated.
- Scheduling of the most hazardous operations for a period when the school is unoccupied, e.g. limit demolition of existing facilities and access to heavy vehicles to school holidays, weekends, after school hours or other times when the school personnel are off-site.
- Building operations could be staggered so that some areas remain in use safely while others are under construction.

There must be a rigorous process of risk assessment to decide which means, if any, are appropriate.

Options for the teaching of science classes during renovations could include:

- altering class timetables so that affected teaching laboratories are not used during periods when building operations are underway.
- modifying the science curriculum to eliminate or reduce non-essential practical classes during the construction period. Some classes could be timetabled into other faculty areas
- transferring classes into other classroom areas:
    - with practical laboratory facilities. For example, schools with separate facilities for junior and senior science may be able to use one facility for some of the other's practical classes. However, smaller specialist teaching laboratories will not be able to accommodate larger classes comfortably or safely.
    - without laboratory facilities, but this would limit or suspend practical work. This may not be possible for senior science classes where practical work is mandatory for assessment. Schools could also consider the renovation of one teaching laboratory at a time, with the timetabled practical classes moved into another teaching laboratory while the one being renovated is out of service.

These options will have undesirable implications for the technical support services for the following reasons.

- The need to transport practical equipment and materials greater distances to teaching laboratories. This will create additional logistical problems and pose a Workplace Health and Safety (WHS) risk to the preparation and distribution of chemicals and materials for practical classes.
- The lack of suitable safety or emergency equipment in classrooms not adequately equipped for additional science activities.
- Fewer available periods for maintenance, set-up and clean-up for science rooms that will be used more often.

Staff must be given prior notice about any scheduled maintenance, service disruption, or if incidental repair work is required. This is important so that any loss of services, such as the water supply, does not compromise safety in the science area.

If preparation laboratories are being renovated there may be a loss of preparation facilities during the renovation period. The transfer of preparation operations into another space, such as a classroom with laboratory capabilities, or another preparation laboratory on the site could be considered as long as there is access to equipment, materials and chemicals that have been packed and stored during the renovations. Safety and security of equipment and materials must be provided.

2.2.2 Managing changes to project specifications, plans and costs

Regardless of the scope or duration of the construction or renovation project, there will some features of the plans or procedures that will require change.

Detailed plans and drawings may have several iterations during the course of the building work. It is vital that the science staff members—both teachers and technicians—have access to the latest version, and be kept informed about the nature of any proposed changes.

Decisions on a seemingly minor matter that are made by a contractor on-site without consultation can have serious repercussions on the final outcome; for example, the position of a switch or a power point could interfere with placement of important equipment that is not shown on the plans.

There must be a clear line of communication with science staff so that they can be consulted before any changes; however minor, are made to the agreed plans.

The availability of contractors and construction equipment or materials can lead to changes to the start or completion date of the project. Science staff must be prepared act quickly to accommodate any changes. For example a change to the start date might mean packing and moving science equipment much sooner than expected, or continuing to work in the area after essential equipment has already been packed for removal.

Contingency plans for scheduling changes or cost overruns should be considered during the planning phase.

2.3 Human factors (ergonomics)

A skilled design team will be able to balance essential technical considerations with the factors that affect people; and so provide an environment that matches user capabilities, limitations and needs. Understanding the interaction of the people with the new science facility will enhance the effectiveness and efficiency of operations, and the safety, comfort and satisfaction of the users.[4] For example, consideration needs to be given to manual handling issues, workflow processes, and traffic routes of staff and students.[5]

2.3.1 Age and physical characteristics of the users

There can be a great diversity of ages and physical characteristics within a school population. In an F–12 school it might be necessary to accommodate students from ages five to eighteen. Even within a senior secondary college the physical size of the students can vary a great deal.

Furniture and fittings in a teaching laboratory can be made adjustable to some degree to meet physical variations in the student population. However, it may be more effective to build separate facilities for a narrower range of ages and sizes.

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[4]Sanders, Mark S and McCormick, Ernest J. 1992. *Human Factors in Engineering and Design 7th Edn,* McGraw Hill Education: New York.

[5]Standards Australia Ltd/Standards New Zealand. 2005. *AS/NZS 2243.1: 2005 Safety in laboratories Part1 Planning and operational aspects,* Standards Australia: Sydney, *Section* 2.2.2, p 9.

2.3.2 Disabilities to be accommodated

In Australia, Disability Standards for Education[6] were formulated in 2005 under the 1992 Disability Discrimination Act 1992.[7] Their purpose was to ensure that students with a disability have access to education on the same basis as a student without a disability. Schools as the education providers are required to make reasonable adjustments to their facilities to accommodate the student with a disability.

The nature and extent of the 'reasonable adjustment' must balance the interests of all parties that will be affected: the disabled student, other students in the same class, the teachers of the student, and the broader school community.

In the case of the science curriculum, the nature of the disabilities to be considered will guide the school's provision of appropriate practical laboratory facilities.

Physical factors such as the texture of flooring materials, the width of doorways and corridors, spacing and height of workbenches may need adjustment to accommodate students with mobility aids such as crutches or wheelchairs. For example, height adjustable benches with a minimum width of 1500 mm for wheelchair access as well as complete with a raised return to contain any chemical spill (to prevent spilling onto the person in the wheelchair) as well as good clearance underneath the bench.

Environmental factors such as lighting and contrast, display boards, acoustics, and the line of sight to the teacher will be relevant to students with visual or hearing impairment. Additional space may be required for a student's aide in the teaching laboratory.

2.3.3 Aesthetics: form versus function

One of the challenges faced by a design team is to meet both the artistic aspirations of the architect and the operational needs of the users. The school administrators may want a facility that is aesthetically pleasing in its surroundings and enhance the school's reputation in the community. The users of the science precinct may be more focused on how well the facility works.

It will be necessary to find the common ground but without sacrificing functionality for the sake of appearance. For example, large expanses of glass windows may fill the rooms with daylight, but that can create problems with sun glare, heat and reduced security.

An elaborate entrance foyer may be impressive but the area could be better used as a teaching laboratory or increased preparation and storage spaces.

The use of unusual curves and angles make for a striking exterior but these shapes can be difficult to work with inside.

2.4 Siting the building

When selecting the position of a new science building or the location of a science precinct, the factors to be considered include:

[6]'Disability Standards for Education 2005', Disability Standards for Education website, http://www.ddaedustandards.info/ (Accessed August 2016).

National Disability Coordination Officer Program. 2015. *Your Right to an Education—A guide for educators and people with disability*, http://www.ddaedustandards.info/PDF/DDA%20e-booklet.pdf (Accessed August 2016).

[7]Office of Parliamentary Council. 2013. *Disability Discrimination Act 1992*, ComLaw Authoritative Act C2013C00022, Federal Register of legislation website, https://www.legislation.gov.au/Details/C2005A00019 (Accessed August 2016).

- the orientation of the building to the surrounding streets, environmental and geographical factors such as the sun, prevailing winds, vegetation, and topography of the site
- the interaction between the surrounding urban area, the science precinct and other parts of the school, e.g. the effects of chemical contamination or disruptive noise, the visual effect of the structure in the streetscape.

There are many advantages in housing new science facilities on one floor, preferably the ground floor, with no steps or changes of level. A single floor level enables the easy movement of equipment via trolleys as well as the delivery of goods and services. If a department is not situated on the ground floor, a goods lift (hoist) may be necessary, which incurs an additional expense.

The plans for a new building will be subject to scrutiny and approval by local government and other statutory authorities. Neighbouring property owners will have an opportunity to comment on the plans and the elements that affect them. These may include:

- changes to natural light caused by the shadows cast by the building or reflections and sun glare from windows
- increased noise from science operations, ventilation or fume cupboard exhaust fans.

2.4.1 Building access issues

2.4.1.1 Security

Some of the valuable equipment and materials used in school science operations are attractive to would-be vandals and thieves, for example, chemicals that could be used to make explosive or incendiary devices or in illicit drug manufacture, electronic balances, computers, data projectors and other ICT equipment.

Teaching laboratories and chemical storerooms must be secured against unauthorised access and also positioned so that their contents are not obvious or easily accessible to a casual passer-by.

Science teaching laboratory or preparation laboratory windows or doors should not be on a school/street boundary where they might invite vandalism or a break-in.

2.4.1.2 Safety

School science laboratories should be quarantined as much as practicable from other school operations and the surrounding neighbourhood. The less desirable aspects of science such as noise or noxious odours can be isolated from other areas. This is especially important in the event of an emergency when the inherent risks should be confined to the science precinct. For example, in the case of a fire or chemical spill in a science laboratory, evacuation of the area will be achieved with less disruption to students and staff if only the science precinct is affected.

2.4.1.3 Emergency services

The science precinct has a higher risk of emergencies related to fire, escape of hazardous chemicals, and personal injury. Ready access for fire brigade and ambulance must be considered when siting the building, for example, the location of doors, the width of corridors and adequate water resources for firefighting.

2.4.1.4 Delivery of good and services

Delivery of the goods and services used in the science precinct needs special consideration. Packages containing hazardous chemicals should not be held in the school's reception or goods-receivable area where most parcels are delivered. The need for secure and safe storage immediately after delivery is essential. Delivery vehicles should have direct access to the building that houses the science chemicals. This will mean that the goods are secured more quickly and with less risk of exposure to school personnel.

There are many science resources that need regular servicing and repairs, for example, laboratory equipment such as fume cupboards, autoclaves, microscopes and electronic balances. Waste treatment, acid traps, hot water services, dishwashers, gas and electricity fittings will need specialist, regular service or repair. Specialist tradespeople should have direct access for their vehicles to carry their bulky, heavy or sensitive equipment and tools.

3 Configuring the workspaces and floor plans

3.1 Introduction

Few Australian secondary schools have the resources to build separate science teaching and practical laboratory facilities. Some compromises in the most desirable features of the two will be inevitable. In particular, flexibility of learning spaces and workstations is more difficult to achieve when mains reticulated services are required. However, basic requirements of laboratory learning environments are non-negotiable. These include:

- sufficient benches and desk space for students to work safely without crowding each other[8]
- access to all services, gas, water, electricity, and drainage.
- an area for students to place their school bags and coats away from traffic routes and workbenches
- escape routes and access to safety equipment.
- circulation routes so that the teacher and students can move around freely, and technicians can distribute materials and equipment into and around the room.

Photographs and diagrams of a wide range of different designs can be found at 'Lab design', The Association for Science Education (UK) website, http://www.ase.org.uk/resources/lab-design/ (Accessed July 2016)

3.2 Staff office areas[9]

Laboratory technicians should have an office area with access to a telephone, computer and peripherals for administration tasks that is separate from, but connected to, the preparation laboratory. Similarly science teachers may also need to have their office space in the science precinct so that they will be close to the science technical resources and staff.

Staff rooms for meals and informal meeting spaces may also be provided but food or drink preparation, storage or washing up *must not be carried out* in the preparation laboratory or teaching laboratories.

3.3 Teaching laboratories and other student learning spaces

As well as the usual teaching laboratory spaces, students may need to have access to private study or 'breakout' areas for research or written work that are not part of the science class program. The size and configuration of these spaces will depend on the number of students and the type of study required.

General-purpose teaching laboratories should be a minimum of 100 m^2 with a minimum wall length of 8 m, to avoid creating a long thin room. The type of layout will determine the overall size of the laboratory and may require a larger room than 100 m^2. If the room is not square, it is important to consider the orientation of the room and whether the teacher's desk should be placed on the long or short wall.

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[8] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010.* op. cit., Section 10.2 Note 1, p45.

[9] Standards Australia Ltd/Standards New Zealand. 2005. *AS/NZS 2243.1:2005*. op. cit., Sections 2.2.4 and 2.2.6, p10.

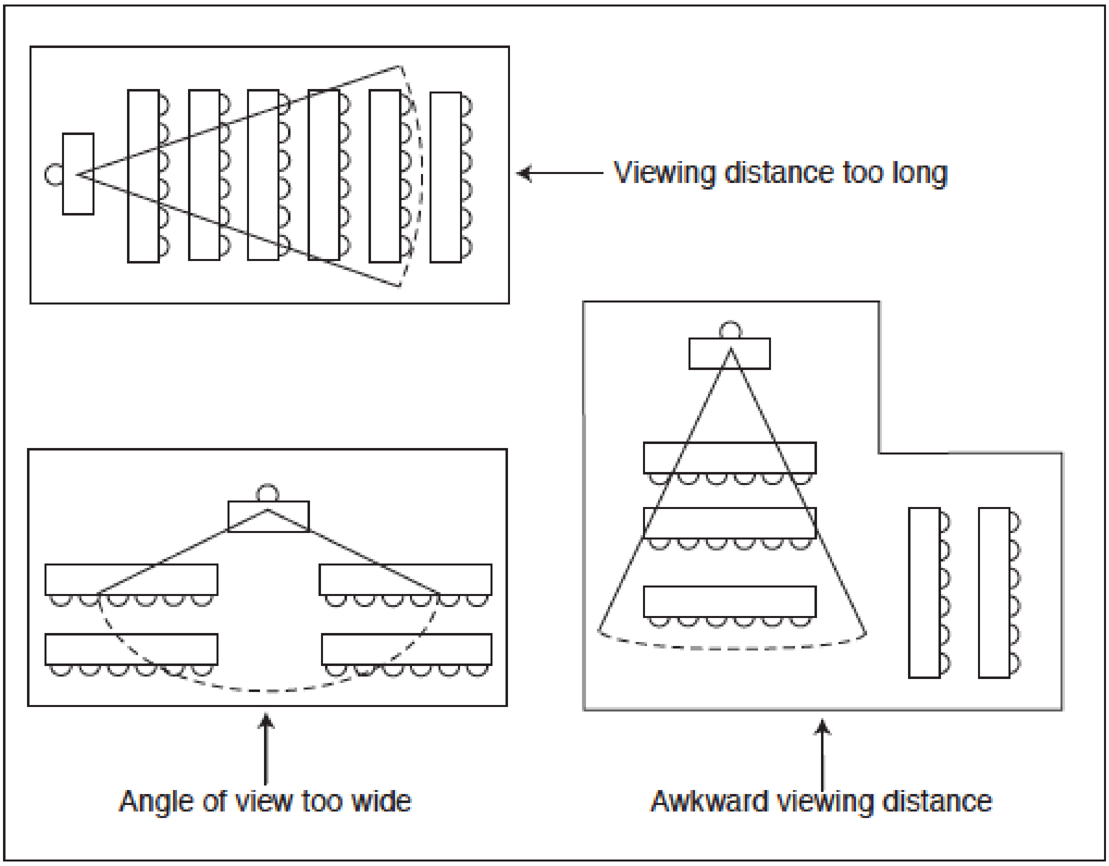

Figure 1: Comparison of length and width characteristics of teaching laboratories [10]

Students generally require 0.36 m^2 of bench space, which is equivalent to two students sitting at a standard table of 1200 mm x 600 mm. Sufficient space is also required between workspaces and examples are given in figures 2–5 below.

The preferred layout of teaching laboratories will depend on the course subjects being taught, the size of the class and age/maturity of the students, and the shape and size of the available space.

In some laboratories, e.g. physics, it is advantageous to have the desks at bench height as this provides additional options to configure the furniture; such as moving the desk/benches alongside the fixed benches to enable the set-up of large equipment such as air tracks.

For designs where the writing tables are separate to the practical benches, a recent trend has been to put carpet, where the writing tables are located. Whilst this may help the acoustics of the room, it negates the requirement for flooring that is required for chemistry and microbiology lessons.

One of the first features to be considered is location of utilities such as water, gas, electricity and drainage.

[10] Adapted from Watson, Lucy; Wadsworth, Alison and Daniels. Richard. 2004. 'Science Accommodation in Secondary Schools: A Design Guide', *Building Bulletin 80* (revised 2004), p. 12, Schools Building and Design Unit, Department of Education and Skills. CLEAPSS website, http://science.cleapss.org.uk/Resource/Building-Bulletin-80.pdf

3.3.1 Utilities such as gas, water, electric power and drainage supplied from under-floor ducts to service pedestals or bollards

3.3.1.1 Centrally distributed laboratory benches combined with writing tables in parallel rows facing the teacher bench

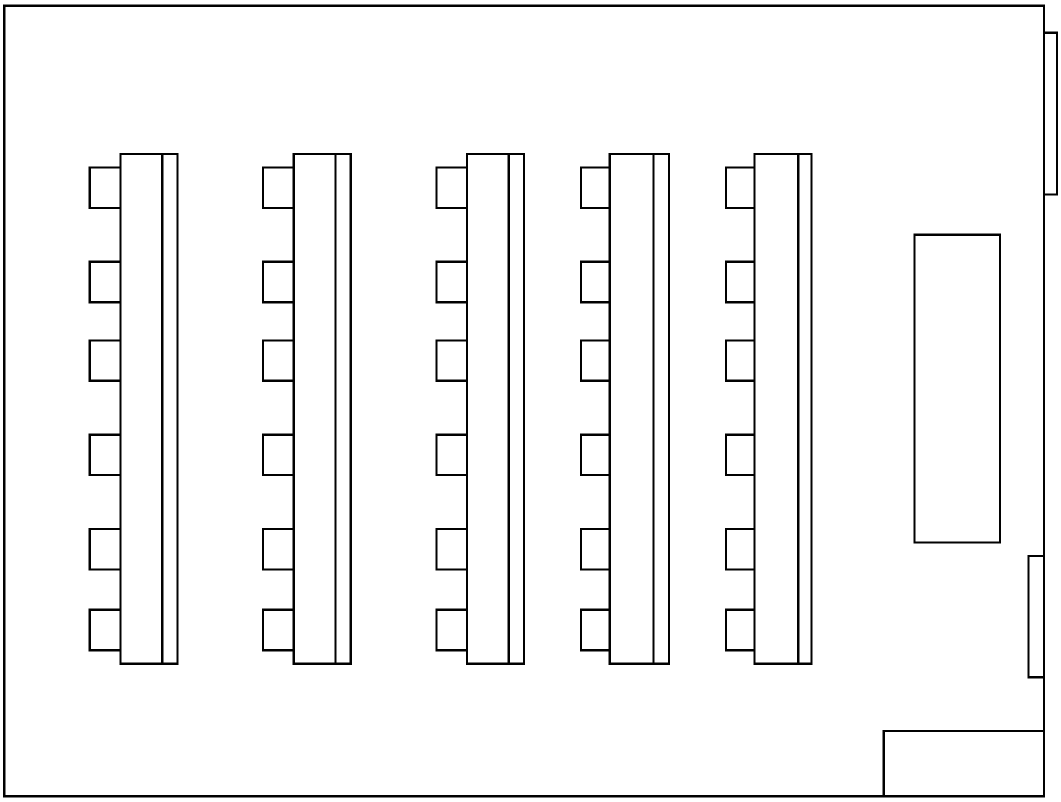

Figure 2: AS/NZS 2982.2010, Section 2.10 requires 1200mm between benches[11]

Positives

- All students face the teacher during theory and practical classes.
- There is less need for students to move around the room during practical activities.

Negatives

- Books, writing materials and ICT devices are subject to damage from water, chemicals, heat or fire during practical activities.
- Utility outlets are subject to tampering during theory classes.
- There is little room for under bench storage of students' laboratory equipment if students must have knee room when seated.
- Student chairs or stools must be removed from the bench area during practical classes or placed under the benches to allow students room to move around during practical work.
- Spacing between the benches/tables must be sufficient for students to move around during their practical work without disturbing the work of other students.

[11] Adapted from Benedetti, Simon; Clark, Margot; Eckhardt, Glenn and Edwards, Jill. 2003. LABCON 2003 Lab design session, p.27, Laboratory Technicians Association of Victoria website, http://ltav.org.au/wp-content/uploads/labcon2003_OHS_Lab_Design_2002.pdf (Reproduced with permission from LTAV).

3.3.1.2 Island benches in a variety of configurations

This configuration arranges all practical benches on one side of the room with the writing desks or tables separate. The positive and negative features are similar to peninsula benches (see section 3.3.2.2 below).

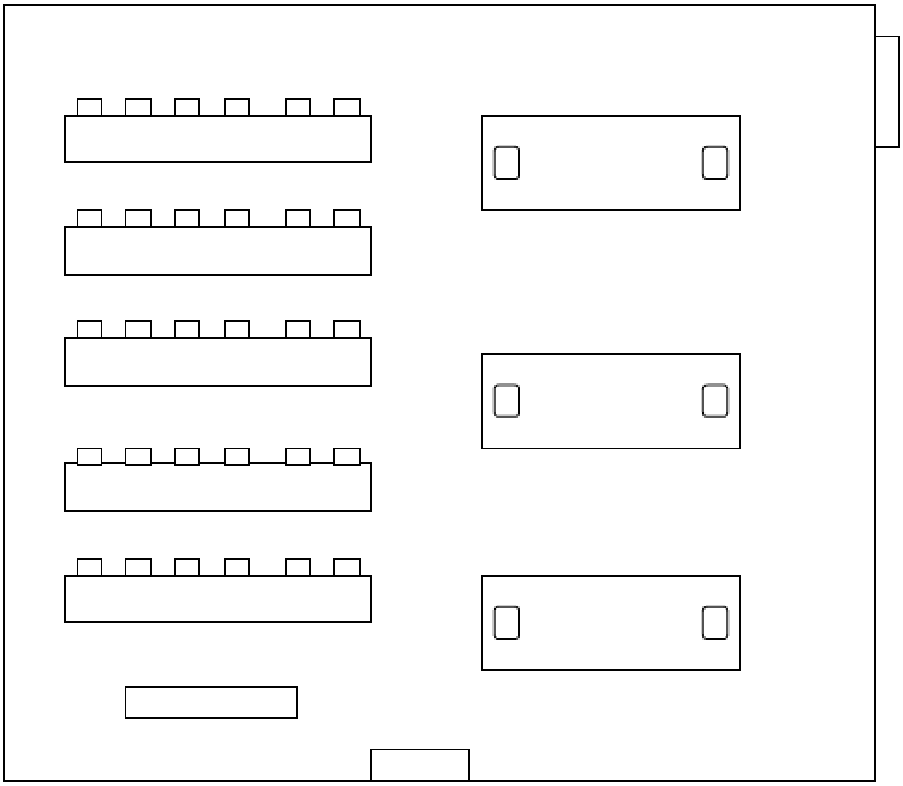

Figure 3: AS/NZS 2982.2010, Section 2.10 requires 1400 mm between workbenches and 1200 mm[12] between workbenches, tables and the walls

3.3.2 Reticulated utilities supplied from the walls of the room

3.3.2.1 Perimeter benches

All reticulated services are provided to benches attached to the walls. Perimeter benches for practical work run lengthwise around three walls while the desks or tables for writing and theory work remain in the centre of the room.

Positives

- Workbooks, writing materials and ICT devices are quarantined from laboratory hazards.
- Less likelihood of tampering with laboratory equipment and service outlets during theory lessons.
- There is some flexibility for moving freestanding desks and tables into different configurations.

Negatives

- During practical work students must work with their backs to the teacher.
- Students are crowded side-by side around the laboratory benches, and obscure the teacher's observation.
- There is more student traffic required between benches and desks.

[12] ibid., p.30.

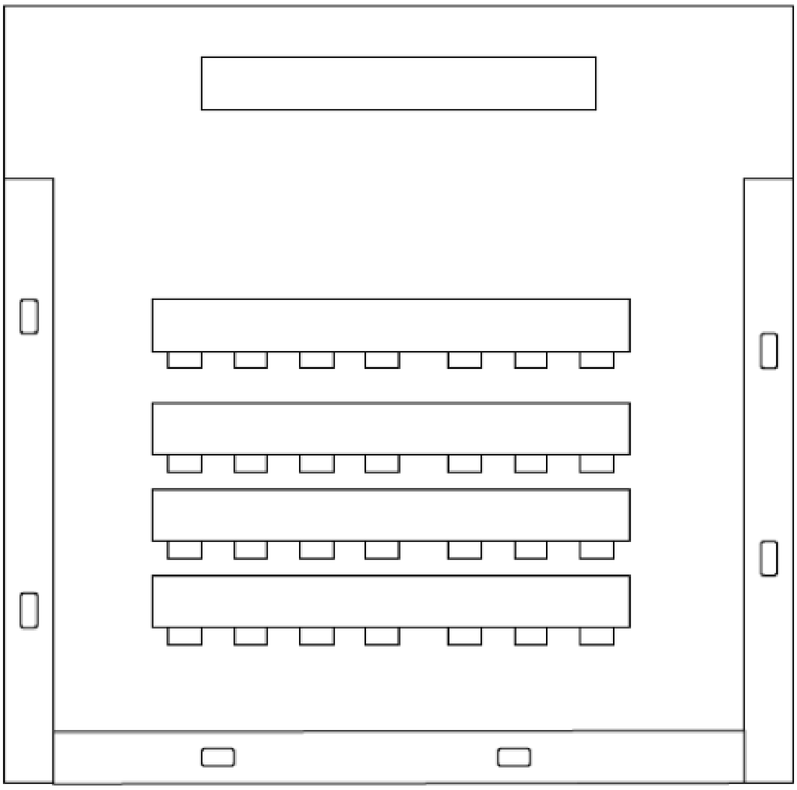

Figure 4: AS/NZS 2982.2010, Section 2.10(b) requires 1200 mm between the workbenches and the writing tables[13]

3.3.2.2 Peninsula benches

Peninsula benches bring the work area further into the centre of the room with benches on two opposite sides of the room. Similar to perimeter benches, all services can be connected from the walls.

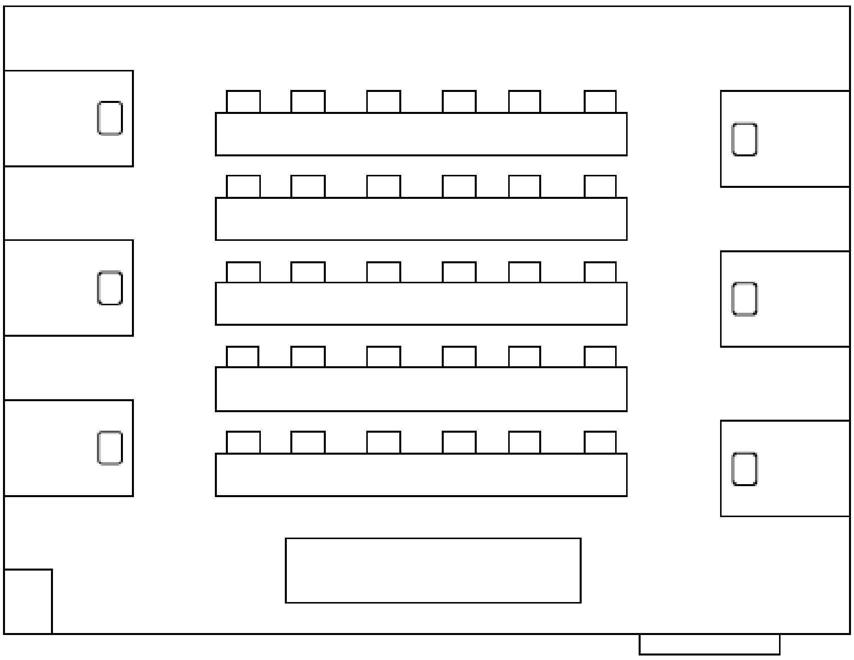

Figure 5: AS/NZS 2982.2010, 2.10 requires 1400 mm between workbenches and 1000 mm between workbenches and writing tables[14]

[13] ibid., p.29.

Positives:

- During practical work at least 50% of the students will be facing the front of the room.
- The students can work in less crowded groups of two or three on each side of the workbench.
- The teacher can circulate around the room and observe the practical work and the students in small groups.
- Workbooks, writing materials and ICT devices are quarantined from laboratory hazards.
- There is some flexibility for moving freestanding desks and tables into different configurations.

Negatives:

- There is student traffic required between benches and desks.

3.4 Preparation areas

Consideration of preparation areas is equally important. For effective support of science teaching and learning, the preparation laboratory and office space for laboratory technical staff must be well resourced.

The preparation areas should be integral to the whole science precinct and not regarded as merely an ancillary service. It is common for preparation areas to be the first to suffer when cuts to the project budget or revisions of the laboratory design are deemed necessary.

The functions of preparation areas are complex. They must service all the different science disciplines and year levels. These functions include:

- preparation of laboratory equipment and materials for classes
- clean up and disposal of equipment and materials after the class has finished with them
- holding and distribution of prepared materials for classes
- maintenance and repair of equipment
- the administration of laboratory resources to meet statutory requirements.

Science teaching and learning will be compromised if the preparation areas are poorly located, badly laid out, too small for their purpose or inadequately resourced.

Direct connection, and an even floor surface with seamless joins between the preparation laboratory and teaching laboratories, is important to facilitate distribution of equipment and materials on trolleys to and from the teaching laboratories, and communication between teachers and laboratory staff. If the teaching laboratory/preparation laboratory layout doesn't allow for connecting doors, then they must be as close as possible along a connecting corridor or space. This will minimize the transport of hazardous materials through areas and periods of high student traffic. For teaching laboratories that are sited in another building or on another level, a separate preparation laboratory should be provided to service those rooms.

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[14] ibid., p.28.

If there are teaching laboratories or preparation laboratories located on upper floors with no direct access from the ground floor then a lift will be necessary for transporting equipment and personnel between floors.

Preparation laboratories should also have a separate entrance for staff members to access without going through a classroom. Traffic through teaching laboratories can be disruptive and distracting. Routes for students between teaching laboratories must not be through the preparation laboratory.

Sufficient space in the preparation area is vital for it to provide effective support for science teaching and learning. There must be plenty of bench space for the many different laboratory functions, and for each technician to work without interference. Equipment such as glassware that is used daily, must be kept close at hand. Space for washing facilities—sinks, dishwashers and drying racks—must also be adequate for their usage. Space for trolley storage and a suitable laboratory refrigerator and freezer must also be included.

A ducted, single-sided fume cupboard provided for preparation use only is recommended and considered best practice. In small rural schools, however a fume cupboard used only in the preparation laboratory may not be financially viable. In this case an AS/NZS 2243.8 standards-compliant double-sided fume cupboard installed in a common wall between the teaching laboratory and preparation laboratory may be acceptable. This is subject to an assessment of all the risks involved.

Note: An office space separate from where hazardous chemicals are handled is required to ensure that computers and other administrative materials and records are not contaminated or damaged; and where laboratory personnel can carry out administrative tasks away from the hazardous laboratory area[15].

Use of the preparation laboratory for students' 'breakout' work or to sit exams is not appropriate; nor is the use of its benches and storage spaces for teachers' paperwork or personal items. Such practices reduce safety and security for both staff and students. Sufficient additional space for those purposes should be included in the design of offices and areas separate to the preparation laboratory.

3.5 Storage areas

Planning for storage areas for science laboratory equipment and materials must also be given high priority.

3.5.1 General storage

Except for chemical storage, equipment and materials that are used frequently can be kept accessible in the preparation laboratory area if it is large enough. A variety of adjustable shelving, small and large drawers and racks for standard equipment trays should be provided. Items used infrequently or reserve stock can be kept in a separate storeroom.

Storage areas in teaching laboratories should be kept to a minimum, and limited to those items used in that room. Consideration could be given to include storage in the teacher's bench—lockable drawers and under-bench cupboards and to include a tray storage area in teaching laboratories possibly near the teacher's bench.

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[15] Standards Australia Ltd/Standards New Zealand. 2005. *AS/NZS 2243.1: 2005 Safety in laboratories Part 1 Planning and Operational Aspects*, Standards Australia: Sydney, Section 2.2.6, p10.

In the case of specialist science classes, such as physics or biology, that have their own dedicated teaching laboratories, equipment and materials specific to those classes can be housed in that room or an adjacent storeroom.

For general science, commonly used items should be stored centrally in a preparation room or adjoining store area rather than teaching laboratories so that they can be collected and distributed without disrupting classes.

Expensive or hazardous specialist equipment that is stored within a classroom should have lockable secure storage. This may include stand-alone or wall mounted display cases with lockable glass doors.

3.5.2 Shelving

There should be a variety of adjustable shelving and small and large drawers. Open shelving systems are useful for items that are needed frequently. They will be susceptible to dust, and the effect of direct light or atmospheric conditions such as variable humidity. Items that could deteriorate in those conditions should not be kept in open storage systems.

Fixed systems can be customised for the specific items that are kept there, again with adjustable shelving. The height of the top shelf should not exceed 1700 mm; a height that can be reached comfortably by most adults, and the depths not exceed 500 mm[16].

Adjustable racking systems with cantilevered supports have specified maximum loads based on the shelf width and are not the preferred option, due to the risk of heavy items at one end destabilizing the shelf or of small objects having the capacity to fall through the gap at the wall.

Except where required for specific items, the width of shelving should not exceed 500 mm. This will allow easier access to items at the back of the shelf without reaching over items at the front.

Modular shelving/racking systems with removable storage tubs of various sizes provide flexibility and mobility for science equipment storage.

Modular sliding storage systems can be useful for some items but they should not be used for chemicals, heavy equipment or breakable items like glassware, or any items that could be affected by the sliding motion. If installed, the systems must have mechanically assisted or motorised means to open and close the units.

Circulation space between any shelving or cupboard units—whether mobile for fixed—must allow people to move freely in the space, access all levels of the shelving without bumping into a shelf behind or other people working there.

3.5.3 Cupboards

Cupboard depths greater than 500 mm are difficult to reach into [17] especially when below waist level. Under-bench storage cupboards are useful where knee room isn’t required for seated tasks.

Cupboard doors should have 270-degree hinges so that they can be opened out without intruding into the circulation routes. Handles should be recessed into or flush with the door surface. Lockable storage cupboards may be necessary for items that are

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[16] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010.*,op.cit., Appendix A6, p.49.

[17] ibid.

hazardous, susceptible to theft or easily damaged. For convenience the locks should be keyed alike with those for other cupboards.

3.5.4 Chemical storage

Statutory laws and regulations in each state and territory cover the features of chemical storage systems. There are many common features that apply irrespective of the substances' classification.

3.5.4.1 General storage principles: see specific data for dangerous goods' storage

- Hazardous chemicals must not be stored in a teaching laboratory[18]. They should be stored in a secure dedicated storeroom with access restricted to authorised staff members only.
- Except for substances required for immediate use, chemicals should not be stored in the Preparation room. A chemical storeroom that is separate from, but connected to, the preparation room is essential to keep chemical hazards controlled.
- The chemical storeroom must have its own natural and mechanical ventilation system with external vents to exhaust vapours and refresh the air at the required rate.[19] The system shall have a capacity of 0.3 m^3 per m^2 of floor space per minute, or 5 m^3 per minute, whichever is greater.[20]
- The storeroom should be of sufficient size to enable the segregation of all incompatible chemicals.
- The storeroom must be protected from direct sunlight and heat. There should be no windows or skylights installed.
- In environments with extreme temperatures, ducted air heating or cooling systems should be included to keep the chemicals within the required storage range.
- There must be no sources of ignition within the chemical store. Switching devices for light fittings or ventilation fans must be outside the storeroom, e.g. a light switch just outside the entrance door. Gas-fired or electric element heaters and other electrical equipment including refrigerators must not be installed within a chemical store.
- Where flammable substances must be kept below room temperature the refrigerators where they are stored must be spark-free to prevent ignition of the vapours inside.
    - Spark-free refrigerators are designed to eliminate generation of sparks inside the body of the unit only. These appliances within a chemical store are a source of ignition for flammable substances stored outside the refrigerator.
- Containers greater than 1 L or 1 kg should not be stored higher than 1000 mm.
- No containers should be kept above 1500 mm
- Liquids should not be stored above solids.
- The surface of shelves and cupboards must be of materials resistant to deterioration in contact with the substances stored
- Packages and containers should not be kept on the floor.

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[18] ibid., Section 10.4, p.45.

[19] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010. op.cit.,* Section 5.7, p27.

[20] Standards Australia Ltd/Standards New Zealand. 2004. *AS 1940—2004 The Storage and Handling of Flammable and Combustible Liquids*, Sydney: Australia, Section 4.5.5, p.47.

Standards Australia Ltd/Standards New Zealand. 2004. AS/NZS *2243.10: 2004 Safety in laboratories Part 10 Storage of Chemicals*, Sydney: Australia, Section 5.4.4, p 26.

4 Provision for Information and Communication Technology (ICT) resources

The use of Information and Communication Technology (ICT) in education has increased rapidly in recent years. Both teachers and students need these resources for research, presentations, digital imaging, data acquisition and analysis in practical work, and for simulation or modelling of experiments that are not practicable to perform in a secondary school environment.

Several examples are described here but the rate of development of new technologies is such that these examples may be superseded or even rendered obsolete over the life of this document. Let it be sufficient to note that designers of schools and science facilities in particular acknowledge that there will be *known unknowns*

The ICT resources in a classroom can be provided in a variety of ways.

- Scheduled access to an ICT classroom that is also shared by the other Key Learning Areas (KLAs). These can be used for whole-of-class research or assessments, leaving the science classroom free to be timetabled for traditional practical activities.
- A bank of desktop computers (PCs) in a 'hub' in a separate room, or segregated from the central classroom area. These will require the student to leave the class area, and work without direct teacher supervision.
- A set of wireless-connected laptop computers or 'tablets' for distribution within the classroom. These can be used with data logging software and various sensors to capture and analyse the results of practical work. These portable devices use less space than do desktop PCs, but they can be vulnerable to damage (if they are used on the workbench during practical classes) and theft unless secure storage areas are included.
- *Bring-your-own devices*[21] (BYOD) that are owned or leased by the students or staff for individual use, including laptop computers, tablets, smartphones and smartwatches. These are becoming more common in schools because they provide more flexible access to ICT, and they have lower capital costs for the school. Students are able to use the school-based applications for all their classroom activities, and have the convenience of having them to use at home.

The increasing use of ICT in the classroom creates the added need for network connectivity. Whereas in the 1990s there may have been one stand-alone PC in a classroom or adjoining office with a dial-up connection to the Internet, there may now be 30 students each with a laptop, tablet and smartphone wanting reliable high-speed remote connections such as WiFi or Bluetooth for each one.

The planning and design of the network connectivity and power needs must include consideration of the role of developing technologies—in so far as they can be anticipated.

[21] Definition: Bring your own device (BYOD)—also called bring your own technology (BYOT), bring your own phone (BYOP), and bring your own PC (BYOPC)—refers to the policy of permitting personnel to bring personally owned mobile devices (laptops, tablets, and smart phones) to the school, and to use those devices to access school network resources and applications.

4.1 Computer hubs

Desktop computers in hubs or break-out research areas that are associated with the science laboratories will need mains power and network data access; one double general power outlet point (GPO) and one local area network (LAN) connection or data point for each PC, and a GPO and data point for each peripheral, e.g. printers, scanners or interactive display screens.

ICT-connected bollards or conduits along the walls will allow flexibility in the arrangement of desks or tables. However, the principles of ergonomics for computer-based tasks must still apply, e.g. the height and spacing of work surfaces, design of chairs, and the configurations of computer monitors and keyboards.

In particular, sufficient space must be provided for the teacher to circulate among the students to supervise and assist them as they work. If the hub is not within the classroom but in an adjoining space, a window panel in the wall between will allow some supervision by the teacher.

4.2 Power sources for laptops and tablets

In most cases, laptop computers and tablets will use their own battery power but some means to recharge the battery or use the device on mains power may be necessary. Teachers will have access to battery charging in their own office spaces. A teaching laboratory may have several mains GPOs to service the laboratory benches but these are not located for convenient or safe connection to laptops or tablets.

Schools have instituted a variety of solutions to this problem including:

- GPOs installed inside student lockers for recharging batteries during recess times
- multiple power points fitted to student tables in teaching laboratories
- extension leads and power boards to convert one power point into several outlets where too few installed GPOs are available
- changeover spare batteries for each device
- onus on the users to ensure they have sufficient battery power for a day's work.

None of these is ideal, and some have significant electrical safety and security issues. Each school must determine its own way to deal with this issue but when GPOs are installed they must be in sufficient numbers and positioned to serve the various devices efficiently.

4.3 Data logging and digital imaging

Along with the increase in range of ICT devices there has been an increase in range of data logging devices. They have become more readily available and much more affordable.

Expensive practical equipment like air-tracks, ultrasonic motion detectors, waveform generators, pH meters, and student microscopes could now be replaced to some extent with an *app*[22] combined with sensors or the inbuilt camera, microphone, accelerometer, power meter, and other devices on a smartphone or tablet computer. For example, the

[22] Definition: App: An application, especially as downloaded by a user to a mobile device.

camera and computer processor on a tablet or smartphone can be used to capture video of motion of an object. An inexpensive smartphone app can be used to analyse the motion. This can free up the space and expense of installing the air track or ticker timers that were required for studying linear motion in traditional physics' practical classes. Similarly the microphone on the smart device can be used with an app to capture and analyse the characteristics of sound.

Other apps can simulate or model movement of celestial bodies, thus providing an alternative for expensive telescopes.

These more affordable options can release capital or recurrent funds for other important installations that might otherwise be only on a 'wish list'.

4.4 Screen-based displays and Interactive White Boards

The quality of screen displays—whether on individual devices or the central 'Whiteboard' screen—is affected by direct light and reflections. The iris of the human eye adjusts to respond to the intensity of the illumination that enters the eye. When the ambient light (natural or artificial) is too bright, the screen display will appear dim by comparison.

The screen-based devices must be positioned to prevent direct light shining onto the screen and to reduce the ambient light near the screen. Windows that allow daylight to shine onto the screen should be fitted with blinds and light fittings over the screen area should be separately switched from the general room lighting so that they can be turned off without dimming the entire room.

Wirelessly connected ICT devices can allow teachers and students to send images to a central screen to be seen by a single class, a group of classrooms or the whole school assembly. These resources may require cabled, audio-visual connections or wireless connectivity to a ceiling mounted projector or LCD displays that are independent of external projection. All these resources require reliable network connectivity but the technology may reduce the need for mass assembly spaces that are expensive to build.

5 Emergency management resources

Planning and design of a school science environment must include provision to deal with emergency situations to control any risk to personnel and limit damage to property.

5.1 Communications

Access to telephone or intercom service in the preparation laboratory is essential for the following reasons:

The variety of hazards that exist in secondary school science laboratories could lead to an emergency situation that can escalate rapidly. Fire, chemical spill, or injury to personnel will require a rapid response. In the event of an emergency in a science class it may not be possible for the teacher to leave the area to call for help.

Laboratory technicians frequently work outside of normal school hours, during recess times and school holidays. School holidays are often the periods when building maintenance is scheduled. The supply of water, gas and power may be interrupted. Painting of walls or large scale floor cleaning may occur. All these factors can increase the risks of injury in laboratory operations. Loss of power will interfere with fume cupboards, ventilation, heating and air conditioning and refrigeration; loss of water will affect the function of eyewash and safety shower stations. Floor cleaning may leave areas wet and slippery, paint fumes and other cleaning solvents may be harmful if inhaled or create a flammable atmosphere. During these periods fewer staff members and students will be in the laboratory area to respond to an emergency.

5.2 Evacuation routes

In Australia, the NCC 2016 Building Code of Australia (BCA) classifies primary and secondary schools, including laboratory areas, as Class 9b buildings[23].

Section D of the BCA requires means that will allow sufficient time for the safe evacuation of the building in the event of an emergency. Such means include consideration of the number of exits, the distance of travel required to reach an exit, and the width of the exit routes and doorways.

The relevant section D1.4(c) does not specifically refer to school science laboratories but only states that the travel distance from any point must not exceed 20 m, or 40 m if there are two available exits.

While these are the minimum requirements, school preparation laboratories and teaching laboratories are subject to greater hazards than a standard classroom or office. Hazards such as the spread of fire or exposure to hazardous substances will require additional means for speedy exit for students and staff in an emergency.

In a school science laboratory a single exit door may not be adequate to allow safe, swift escape from a hazardous situation. For instance, a fire, gas or electrical hazard, or chemical spill may occur near the exit door obstructing safe egress. In a teaching laboratory there may be as many as 30 people who need to make a quick exit.

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[23] Australian Building Codes Board. 2016. *National Construction Code 2016. Volume One. Building Code of Australia Class 2 to Class 9 Buildings*, ABCB: Canberra, ACT, Part A3 Classification of Buildings and Structures, Section 4.5.5, p.39, http://www.abcb.gov.au/Resources/Publications/NCC/NCC-2016-Volume-One (Free access upon registration).

Consideration of the exit provisions should include the behaviour of the students or staff members in an emergency situation. Aisles and doorways may need to be wider than the minimum to accommodate exit for a large number of people. Exit signage must be prominent and clear.

A risk assessment considering egress should be conducted to ensure that escape from an emergency situation in a laboratory environment is swift, direct and safe.[24] The following provisions are considered best practice

- Preparation laboratories and teaching laboratories should have at least two separate means of egress; at least one with access to the outside or to a corridor that has external exit.
- Where there are two or more doors the distance between them should be the lesser of 12.5 m or 20% of the perimeter of the room. For example, in a 10 x 11 m teaching laboratory the distance between exits should be at least 8.5 m.
- Small laboratory sub-compartments such as a chemical storeroom may have only one egress door provided that the distance of travel to the exit from any point in the room does not exceed 7 m.
- The doors should have a glazed vision panel so that a person can see what is on the other side of the door. In a fire door a vision panel must not compromise the fire rating of the door.
- The doors must open in the direction of egress, and be not lockable against egress.
- Where doors open to a corridor they should be recessed so they do not impede traffic in the corridor.

5.3 Fire

A secondary school science precinct has teaching laboratories, preparation laboratories and storage and handling of materials that present a foreseeable risk of fire or explosion.

Automated fire and gas detectors and alarms, and extinguishing systems are established means to manage the risk of injury to personnel and damage to property. Each teaching laboratory, preparation laboratory and chemical storeroom must have the equipment appropriate to its operations.

Smoke-sensitive fire alarm systems in teaching laboratories, preparation laboratories and adjoining spaces are impractical because they may be activated unnecessarily. Some science activities produce smoke with no risk of a wide spread fire. Thermal detectors provide a reliable alternative protection.[25]

5.3.1 Extinguishers

The *Building Code of Australia* Part E1 covers the requirement for fire suppression or extinguishing systems such as sprinklers, fire hydrants and hose reels in great detail. Class 9b secondary school teaching laboratories and preparation laboratories are

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[24] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010. op.cit.*, Section 2.11 p. 18.

[25] CLEAPSS. 2009. *G14 Designing and Planning Laboratories*, ASE (UK) website, 3.10 Fire Prevention and Control Measures, p. 20, http://www.ase.org.uk/documents/lab-design-designing-and-planning-laboratories/

usually not required to have sprinklers.[26] See the BCA table 1.5 for requirements for school occupancy criteria.

In the event of a fire in a teaching laboratory or preparation laboratory the safety of students and staff is a priority. Firefighting should be left to the Fire Services, however, ready access to a correct fire extinguisher could reduce the fire spreading further.

Both CO_2 and ABE Dry powder portable fire extinguishers are suitable for electrical and chemical fires but can also be used on paper, wood and other solid fuel fires.

AS 2444-approved fire extinguishers and fire blankets [27] should be installed in each teaching laboratory and at least one in each preparation laboratory and near the entrance to each chemical storeroom.

5.4 Gas or electrical emergencies

If an emergency arises that involves use of gas or electricity, the mains supply to the laboratory benches may need to be shut off quickly.

Each teaching laboratory and preparation laboratory must have a shut-off gas valve and mains electricity switch that is visible and accessible to staff members and students. Teachers and laboratory technicians may need to switch off the mains very quickly in an emergency, but it may be the teacher or the technician who is the victim of an emergency situation in the laboratory. Students should also know where the control is and how to operate it. The students may be the only other personnel present who can activate the safety cut-off devices.

The teaching laboratory safety electricity switches and gas isolating valves should be visible from a distance, easily accessible and with appropriate signage.

While an isolating control in this location could be activated mischievously, such a minor inconvenience is outweighed by the added safety it provides.

Gas outlets must have an isolating valve that is located adjacent to the teacher's bench. Power to general-purpose outlets (GPOs) must be supplied through a master control switch operated by a suitably labelled push-button, located near the teacher's bench adjacent to the mains gas isolating valve.

Once activated the gas/electricity safety switch should be locked against accidental or mischievous activation by a key-operated manual reset.

The key for resetting the isolating switch or valve should be readily available to staff members. If not, and the key is difficult to locate when needed, the class may be left without gas or power unnecessarily.

[26] Australian Building Codes Board, op. cit., Part E1.5 Sprinklers, p 245

[27] Standards Australia Ltd. 2001. *AS 2444—2001 Portable fire extinguishers and fire blankets—Selection and location*, Standards Australia: Sydney

Figure 6: Isolating valves and switches shall be provided with a legible and durable label indicating the service.

The safety isolating control to the preparation laboratory must be separate to the teaching laboratory controls so that laboratory operations in one area are not affected by an incident in the other. In the preparation laboratory, the switch should be close to one of the exit doors so that it can be activated as the room is evacuated[28]. Preparation laboratory gas and power isolators need not be protected by a keyed reset.

The gas and power supply to a fume cupboard must not be activated by the safety switch or valve for the teaching laboratory or preparation laboratory. Sudden interruption to the power or gas supply to the fume cupboard may cause additional hazards during an emergency. The fume cupboard must have its own safety isolator for gas and electricity [29]

Residual Current Devices (RCDs)

A residual current device (RCD), or safety switch, protects a person from the most frequent cause of electrocution—a shock from electricity passing through the body to the earth. It can also provide some protection against electrical fires.

RCDs are electrical safety devices designed to immediately switch off the supply of electricity when electricity leaking to earth is detected at harmful levels. They offer high levels of personal protection from electric shock.

In accordance with the electrical safety regulator in each jurisdiction, each circuit in a school science precinct should be protected by an RCD[30]. Exemptions may be allowed for devices that have intrinsic earth leakage such as heaters, or some sensitive equipment that needs greater reliability and continuity of supply such as IT and audio-visual devices. GPOs without RCD protection must be clearly labelled as such.

Note: The RCDs do not protect against all sources of electrical hazards. They do not replace the need for emergency cut-off switches in each laboratory.

A notable exemption to the RCD requirement is power to fume cupboards. These must be connected to the electricity supply via their own dedicated circuit that will not be interrupted when an RCD on a general circuit is activated. This will ensure that fume cupboard extraction fans keeps operating to exhaust hazardous vapours.

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[28] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010. op.cit.*, Section 3.4, p. 21.

[29] Standards Australia Ltd/Standards New Zealand. 2014. *AS/NZS 2243.8: 2014 Safety in laboratories Part 8 Fume cupboards,* Standards Australia: Sydney, Clause 2.2.1, 2.2.4, pp. 11–12.

[30] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010. op.cit.*, Section 4.2, p.24.

5.5 Water overflow and flooding

Each teaching laboratory and preparation laboratory should also have an individual water stop valve. While control of a water leak is not usually urgent, prompt action to shut off a broken faucet or stop an overflowing sink can prevent electrical hazards, damage to fittings and reduce the risk of slipping on a wet floor.

Individual room controls will prevent inconvenience to other locations when water must be turned off.

5.6 Spills and accidental release of hazardous materials

Accidental release or spills of chemicals or other hazardous materials such as harmful microorganisms or radioactive material may occur at some time in a science laboratory precinct. Careful planning of the laboratory and chemical storage areas can control the risk that such an event presents. Any spill or release must be contained.

In laboratory stores and decanting areas, containment of a spill can be achieved by bunding[31] the floor area, and sloping the floor slightly so that spilled material can be swept or pooled to be collected, but the spilled material must not be allowed to enter the waste water drain or sewer.

Equipment to treat and collect spilled material should be accessible in each area, together with appropriate signage and training in its safe use. The recommended contents of spill kits vary depending on the hazards present and the risks assessed.[32]

5.7 Eye wash and emergency shower

In secondary school science laboratories, the risk of eye and skin contact with hazardous substances is high. Risk Controls such as the use of Personal Protective Equipment—safety glasses and gloves—may reduce the risk but, in particular, eye injuries from chemical contact must be treated immediately. Each science teaching laboratory and preparation laboratory where hazardous substances are used should have either an eyewash or eye/face wash station and separate shower or a combination shower and eye wash device to meet *AS 4775:2007 Eye wash and Safety Showers*.

The device must be located within a maximum 10 sec travel time, or no more than 15 m unobstructed travel distance.

The eye/face wash must deliver drinkable (potable) water at sufficient flow rate and duration.[33] First Aid guidelines for chemical burns to the eye state that the eye must be flushed with cool, running water for a minimum of 20–30 minutes[34].

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[31] Standards Australia Ltd/Standards New Zealand. 2004. *AS/NZS 2243.10.* op.cit., Section 5.4.3.2, p26–27.

[32] Standards Australia Ltd/Standards New Zealand. 2006. *AS/NZ 2243.2:2006 Safety in laboratories Part 2 Chemical Aspects*, Standards Australia: Sydney Standards Australia: Sydney, Appendix C, p. 28.

Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZ 2243.3:2010*, op. cit., Section 9, p.106; Section 12, pp.127–129.

Standards Australia Ltd/Standards New Zealand. 1998. *AS/NZS 2243.4 1998 Safety in laboratories Part 4 Ionising Radiations,* Standards Australia: Sydney, Section 10, pp.37–40.

ARPANSA. 2012. *Use of Radiation in Schools, Part 1 Ionising Radiation* paragraph 5.4, ARPANSA website, http://www.arpansa.gov.au/pubs/rps/rps18.pdf

Both plumbed-in and self-contained units are described in *AS4775*. See Appendix F for selection of the most appropriate unit.[35]

The important factors are:

- the need to flush the eyes without delay
- the quality of the flushing fluid, and
- the duration of the fluid supply.

The best means to achieve these is to install a plumbed-in eye/face wash with an aerator fitting in each teaching or preparation laboratory where hazardous substances are used. In cases where a potable reticulated water supply is interrupted or not available, a self-contained eye/face wash unit may be adequate, provided the quality and volume of fluid or potable water is sufficient to flush the eye for the recommended time.

5.8 First Aid supplies

Laboratory emergencies that cause injuries to personnel will require access to appropriate First Aid materials and procedures.

Each state and territory's Workplace Safety jurisdiction has its own Code of Practice that covers the number, location and content of First Aid kits, and the criteria for trained First Aiders.

Schools should have a central well-resourced First Aid facility with trained First Aiders. The science precinct should have First Aid-trained personnel and all necessary First Aid equipment in its kits at close hand.

Injuries that are common in school science departments are cuts from sharp equipment and broken glass, burns from hot equipment, and burns from chemical contact with skin and eyes.

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[33] Standards Australia Ltd. 2007. *AS 4775-2007 Emergency eyewash and shower equipment,* Standards Australia: Sydney, Section 7, p10, Section 8, p13.

[34] Eden, Kym. 2014. *Fun with First Aid*, 12th Edn, National First Aid: Victoria. p. 170

[35] Standards Australia Ltd. 2007. *ibid.*, Appendix F, p. 28.

6 Utilities

6.1 Climate control and comfort

Throughout Australia the seasonal variations in climate are very wide. Schools must plan for effective and efficient control of the worst of these conditions to maintain adequate thermal comfort for their staff and students. The factors to be considered are air temperature, radiant heat from windows and other sources, humidity, air speed, the amount of physical activity, the amount and type of clothing worn. The degree of comfort or discomfort that is experienced varies with each individual. The optimum temperature range for laboratory operations is 22^{o} C +/- 2 ^{o} C.[36]

In a science-teaching precinct, the climate control planning must extend to the conditions for storage and handling of chemicals, temperature-sensitive equipment, perishable materials, and any live plant or animal specimens or cultures. The requirement for chemical stores is that 'Substances which are unstable at ambient temperature shall be kept in a controlled temperature environment set to maintain an appropriate temperature range.'[37,38]

Some management of extreme heat, cold and humidity can be achieved by planning the building to optimise sunlight and ventilation. It is likely that some artificial control of the indoor climate will be necessary, including the periods when the school is closed. School summer holidays, weekends and overnight can experience temperature extremes that won't affect the school personnel but can have damaging effects or create hazardous situations for living organisms, chemicals, materials and equipment. The position of ceiling fans and air-conditioning units can affect laboratory equipment. Bunsen burner flames may be blown out. Increased turbulence may interfere with airflow to fume cupboards.[39]

Devices to control climate

Cooling:

- Reflective film, blinds or curtains can reduce radiant heat through windows. Internal soft windows coverings such as blinds and curtains may not be suitable for laboratories where they can be contaminated by microbes or chemicals.
- External screens, awnings, shutters and wall and ceiling insulation can reduce radiant heat from solid surfaces.
- Air movement from ceiling fans and natural or artificial ventilation cool a person by evaporating perspiration from the exposed surface of the skin. This is ineffective when a person is wearing the protective clothing that is usually required in a laboratory environment. Long sleeves, laboratory coats, and gloves necessarily reduce the skin surface that is exposed to the air.
- Evaporative air-conditioning will cool the air but also increase to the humidity that in turn will affect the body's ability to cool itself.
- Refrigerated air-conditioning is effective at cooling and reducing humidity.

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[36] Standards Australia Ltd/Standards New Zealand. 2005. *op.cit., Section 2.7.3* p. 13.

[37] Standards Australia Ltd/Standards New Zealand. 2004. *AS/NZ 2243.10:2004, op.cit.*, Section 2.5 (l), p. 13. Reproduced with permission from SAI Global Ltd under Licence 1407-c117.

[38] For further information see 'Legal temperature for the chemical storeroom in schools', Question to Science ASSIST website, https://assist.asta.edu.au/question/3647/legal-temperature-chemical-store-room-schools (March 2016)

[39] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010. op.cit.,* Section 5, pp25–27.

Heating:

Heating appliances with exposed flame, e.g. gas or oil pilot lights, exposed heating elements and hot surfaces are sources of ignition that are prohibited in an environment where there may be flammable vapours. Suitable methods include:

- central heating via ducted warm air
- stand-alone radiant panel heaters which have no exposed ignition source
- reverse-cycle air-conditioners.

Any climate control system should be evaluated for any undesirable features such as noise that it generates and ongoing maintenance issues.

6.2 Water supply

School science preparation laboratories and teaching laboratories require an adequate supply of potable water for preparation of materials, some common laboratory procedures such as distillation or vacuum filtration, washing of equipment, and for personal hygiene, First Aid and safety equipment.

Local water authorities require that no 'back-flow' from the laboratory can contaminate the potable water supply to other outlets. Back-flow prevention valves or roof-mounted break-tanks to gravity feed water to the laboratories without the risk of back flow may be required[40].

Plain potable water may be suitable for many preparation procedures, but chlorinated water can be unsuitable for some processes.

Distilled or deionized water is usually required for senior chemistry and biology, so provision should be made within the preparation laboratory to mount a deioniser or distillation equipment to be connected to the mains water supply.

Distillation equipment can produce very pure water for analytical or sensitive biological processes but it can be very slow and inefficient in its water use unless the condenser coolant water is recycled. In locations where the water supply is restricted, deionized water is preferable to distilled water except for those procedures that need very pure water.

Teaching laboratories and preparation laboratories also need a supply of hot water for hand washing for hygiene and cleaning of laboratory equipment. Hot water can be supplied from a central storage system, a small local storage system that supplies one or two laboratories, or an instantaneous system that heats and delivers hot water as required.

The choice of which is preferred will depend on the volume and temperature of hot water that is needed.

Various state and territory guidelines cover the optimum temperature for stored hot water. Prevention of the growth of *Legionella* bacteria requires a temperature greater than 60 ^{o}C. A temperature of not more than 50 ^{o}C is should be delivered for hand washing facilities. Sinks used for cleaning of laboratory equipment can be provided with water at a higher temperature. See the relevant state or territory regulations for details.

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[40] Griffin, Brian. 1998. *Laboratory Design Guide*; Architectural Press: Oxford, UK, p.48.

Most water use in a school science laboratory occurs in the preparation laboratory for the washing up processes. While laboratories in large research and commercial settings may incorporate a separate glass washing facility, few schools have the capacity for such a luxury. However, a purpose-designed glass/dishwasher machine can save water and time for technical staff, but some equipment will need to be washed manually. A domestic dishwasher may be adequate for some glassware. Whether a domestic or laboratory washer is more suitable will depend on the quantity and type of equipment to be washed and the comparative costs. Each school should make its own assessment of these factors.

The sinks and taps in the laboratories need consideration of their placement and design.

6.2.1 Sinks

Each laboratory workstation including the teachers' bench in a teaching laboratory should have its own sink, or at least one shared between two workstations.

Traditionally, laboratory sinks have been made from a hard ceramic with a white vitreous enamel internal finish—sometimes known as 'Belfast' sinks. They have the advantage that they can resist staining and damage from solvents and corrosive substances. They are also very hard. Glassware and porcelain equipment is likely to shatter if dropped into the sink.

Sinks made from synthetic materials such as cast epoxy resin, polypropylene and mineral filled resins are easier on breakables. They are lightweight and have good chemical resistance but less resistance to heat and staining.

Laboratory sinks in the student workbenches should be located for easy access. Sinks at the wall end of a perimeter bench can be difficult to reach for cleaning.

In addition to the workstation sinks, the teaching laboratory should have some larger sinks with drainers for washing glassware, disposal of low-risk wastes and separate sinks for hand washing and installation of eyewash facilities.

Stainless steel may react with corrosive chemicals in a laboratory environment but a high commercial 306 grade will resist corrosion more than domestic 304 grades.[41] Domestic-grade stainless steel sinks and drainers are not suitable for school, science laboratories. While they may be less expensive than a commercial grade they will degrade and need replacing sooner.

The sinks that are used for washing up—both in the teaching laboratories and preparation laboratory—must accommodate large items such as measuring cylinders, pipettes and burettes (which can be more than a metre long) and pneumatic troughs so they may need more length and depth than a domestic sink, but sufficient height to allow the user to work without stooping.

The bench area around sinks is vulnerable to damage from water. In the case of the traditional under-mounted sink, the edge of the workbench overhangs the sink. This is effective at draining liquid waste into the sink but the edge of a laminate substrate is exposed to repeated contact with water and other liquids.

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[41] Australian Stainless Steel Development Association. 2012. *Australian stainless reference manual 2012*, Australian Stainless Steel Development Association: Brisbane.

Figure 7: Traditional under-mounted sink (L) and drop-in sink (R) [42]

A drop-in sink protects the edge of the bench by having the edge or lip of the sink fit over the bench surface. The lip can extend to include a drainer.

6.2.2 Taps (faucets)

Taps over the sinks in the laboratory should be non-rotating. This will reduce the amount of water splashing over the bench, either by accident or deliberate misuse. A Swan-neck/gooseneck or high clearance pillar design has the tap nozzle 225–270 mm above the sink. The tap handle can be mounted at the base or on the top of the fitting.

Figure 8: Swan-neck and pillar taps[43]

For day-to-day use, an aerated water softener fitting will reduce splashing and the water jet pressure. A hose fitting may be necessary for distillation kits or Venturi-type water–operated aspirator pumps for vacuum filtration.

Domestic-type chromium-plated taps will corrode and deteriorate quickly in a laboratory environment. Epoxy-coated taps may be more expensive but they will last longer. They are available in a range of colours, styles and sizes.

6.3 Vacuum for filtration systems

Central laboratory vacuum systems are usually unnecessary for secondary school science. Electric or hand-operator vacuum pumps are usually sufficient for physical science activities.

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[42] Adapted from CLEAPSS. 2009. *op.cit.,* p. 40

[43] Images: (L) http://www.cadblocksfree.com/ (R) http://www.laboratoryanalysis.co.uk/

When vacuum filtration is required in senior chemistry activities, Venturi-type water aspirator pumps can be connected to taps over a laboratory sink; either by a hose and clip or by a semi-permanent screw fitting. They are quite inexpensive and simple to install.

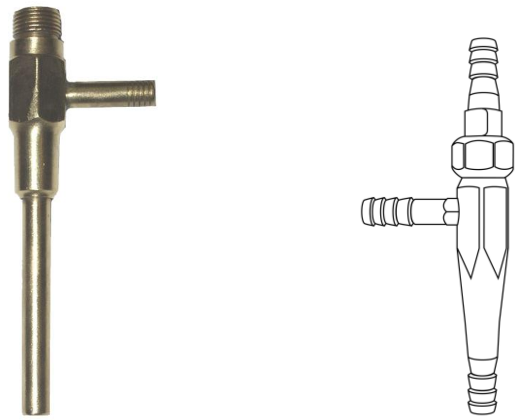

Figure 9: Water aspirator (Venturi) tap fittings: (L) screw-on fitting, (R) hose fitting

In facilities where the mains water pressure is too low to create sufficient vacuum from the Venturi effect a mechanical vacuum pump system may be adequate.[44]

6.4 Waste water systems

Hazardous wastes can damage the sewer infrastructure and cause a hazardous environment for wastewater and sewer maintenance workers. As a general rule, no hazardous waste from the school laboratories should be flushed into the waste water systems. In practice, it is not possible to prevent some residues from science activities from going down the sink.

Solid material can be captured by the P-traps or S-traps connected to the laboratory sinks.

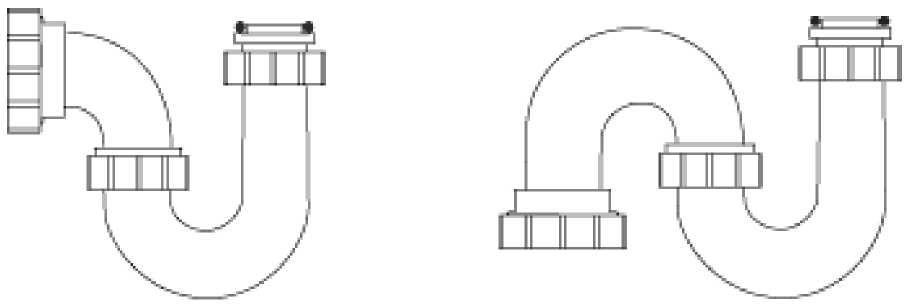

Figure 10 P-trap and S-trap sink waste outlet: curved base section can be removed to collect and recover solid materials[45]

Waste outlets from laboratory sinks should not to be interconnected. Each sink should have its own P or S trap installed to discharge waste into the sewer. Interconnection via

[44] For guidance on the safe use of vacuum systems in schools see ‘SOP for water aspirator/vacuum pump’, Question to Science ASSIST website, https://assist.asta.edu.au/question/3211/sop-water-aspiratorvacuum-pump (September 2015).

[45] Line drawings: www.diydata.com

fixture pairs that are common in domestic plumbing installations are not permitted for the laboratory setting[46]. In addition, fume cupboard sinks should not be interconnected with any other sink and floor waste plumbing in the teaching laboratory and preparation areas.

Each state and territory regulator and/or local water and sewerage authority has its own regulations about disposal of waste into the sewerage or storm water systems. Local water authorities often require distribution or dilution tanks. They hold and dilute waste before it is discharged to the sewer.

Local water authorities may require the school to enter into a Trade Waste service agreement (or similar) that will govern the disposal of wastes from the premises.

In the past, liquid wastes were controlled to a limited extent by installing traps that neutralised acidic waste before it entered the sewer. The acid traps, also called 'neutralising tanks', have calcium carbonate or 'marble' blocks that react with acidic wastes. The blocks become depleted as they neutralize the acids, and must be replaced regularly. The tanks themselves can become contaminated with waste solids, and must be cleaned out regularly or they will become the source of hazardous residues. Please note that acid traps are limited to acidic waste only. They do not treat other types of chemical waste.

Note: It is best practice to treat laboratory waste in the laboratory to render it safe for disposal, or to safely store for disposal by a licensed waste disposal contractor.

6.5 Reticulated gas

Reticulated natural gas supply (mains gas) is available in most major cities and urban areas in Australia. It is safe and economical to use. Natural gas is methane, CH_4. Other components, e.g. ethane, propane, butane and impurities such as water and sulfur are removed in the refining process.

The bottled liquid petroleum gas LPG that is supplied to premises in Australia is usually propane LPG (propane) C_3H_8, unless butane is required for a specific purpose. In some regional and rural areas LPG is the only domestic heating/cooking gas available.

For school science laboratories reticulated mains gas is preferred to reticulated fixed-bottled gas wherever possible. A mains gas supply is not subject to the vagaries of a delivery schedule, nor onerous storage conditions. Each relevant state and territory energy authority regulates the storage of LPG gas bottles, but the required conditions include security from accidental damage or vandalism, management of the risk of gas leaks and explosion, and segregation of the storage area from other areas. This is usually in a locked caged enclosure, which allows ventilation as well as provides protection from vandalism.

However, even where natural gas is generally available a supply of reticulated fixed-bottled LPG to a science laboratory precinct can be a short-term solution if connection to the mains is impracticable; for example when a 'transportable' science-teaching laboratory has no gas mains connection, or as a temporary supply during building or renovations.

[46] Standards Australia Ltd/Standards New Zealand. 2015. *AS/NZS 3500.2: 2015 Plumbing and Drainage, Part 2: Sanitary plumbing and drainage* Standards Australia: Sydney, p. 165.

6.5.1 Gas appliances

Common laboratory gas appliances include Bunsen burners, MEKA burners, gas heaters, and stovetops. Each will be made to use with either natural or LP gas. The two types of gas supply are quite different, and the appliances designed for one type are not interchangeable with the other because:

- the energy content is different. LPG has higher calorific value than natural gas.
- the oxygen: gas ratio is different. LPG requires more oxygen to burn efficiently, approx. 25:1. Natural gas' oxygen to gas ratio is 10:1. LPG is delivered to the appliance in smaller quantities at a higher pressure than mains natural gas, and draws more oxygen in with it.

Using mains natural gas with an appliance fitted for LPG will deliver a smaller, cooler and a less efficient flame. Conversely, a natural gas appliance used with bottled LPG will result in a very intense, hot flame that can be quite dangerous for the user.

Alternate heating sources

If the provision of a safe and compliant natural or LPG gas reticulated supply cannot be achieved then the use of alternate heat sources, such as portable electric hotplates, heating mantles or water baths, is recommended. Indoor use of portable camping burners is prohibited.

CAUTION: Use of portable Bunsen burners with disposable gas canisters

It has been reported that portable Bunsen burners connected to disposable gas canisters have been promoted as an alternative to reticulated gas supply in schools. **This is not recommended.**

A number of state and territory energy safety regulators have advised recently that the use of these **portable butane Bunsen burners is not recommended in schools** due to significant safety concerns regarding the storage and handling of butane cartridges, the lack of a central emergency shut off and concerns regarding the supervision and training aspects of their use. In some jurisdictions their use in schools is prohibited.

The most hazardous design of portable Bunsen burners are those devices which have an assembly clamped on top of the gas canister. The gas is released when the assembly punctures the canister. [47]

Figure 11: A typical portable Bunsen burner with puncture-type disposable gas canister

[47] 'Portable Bunsen burners', Question to Science ASSIST website, http://assist.asta.edu.au/question/3059/portable-bunsen-burners (December 2015).

The potential for gas leakage is high with this type of canister; sometimes occurring when the puncture procedure is faulty or not performed correctly, or if the burner assembly is removed before the canister is empty. As the canister has no valve or sealing mechanism, the canister cannot be safely removed from the burner until it is empty. The puncture style portable Bunsen burners can pose significant risks to the users.

- Explosion: Removal of the burner assembly prior to the canister being empty has the potential risk of a fireball or explosion if the burner is in operation, there is a nearby source of ignition or the burner is still hot.
- ‘Cold’ burns: The cooling caused by the rapid loss of gas could cause ‘cold’ burns if the canister is being handled.
- Tipping over: The height to width ratio of the burner assembly when attached to the canister enables it to be tipped over easily.
- There can be no master safety shutoff as is required by AS2982:2010 3.4. This presents a serious uncontrolled risk of fire and explosion, all the more serious if students in a science practical class are using several of these devices.

In jurisdictions where they are not actually prohibited, portable Bunsen burners with disposable gas canisters should only be used following a site -specific risk assessment regarding their use. This should be in limited and strictly controlled circumstances.

- When a supply of reticulated natural or LP gas is temporarily unavailable.
- When the activity is a demonstration carried out by a teacher or other appropriate adult who has been trained in the correct usage and safety requirements.
- Students should not use the devices during practical classes as a substitute for standard Bunsen burners with a reticulated gas supply.

6.5.1.1 Gas outlets on laboratory benches

Each student workstation in a teaching laboratory should have one gas connection for a Bunsen burner. These outlets are available in single, double or multiple configurations to suit a variety of laboratory layouts.

The optimum position of the gas outlets will vary with the configuration of the laboratory workstations. For an island or peninsula bench layout where groups of students work on either side of the bench, the gas outlets should be mounted near the centre line of the bench—either on the bench top or within a service bollard.

On perimeter or other bench arrangements where groups of students work only on one side of the bench, the gas outlets should be mounted close to the rear of the bench—either on the bench top, a service bollard or on a splash back or raised rear panel.

In any configuration the placement of the gas outlets should allow the maximum free space along the bench for other equipment. The users need plenty of space to work without interfering with others sharing the same bench. Configuration should also allow ready access to the gas outlet’s control tap without the need to reach across the Bunsen burner flame.

Push-on turret connectors have been the preferred option for Bunsen burners in Australian schools for many decades.

Note: The previously common ‘quick-connect’ bayonet fittings are subject to deteriorating seals, and the likelihood of gas leaks. They have been prohibited in

Victorian schools since the 1990s. In other jurisdictions they are not recommended for schools.[48]


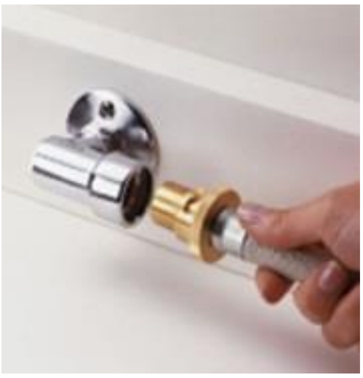

Figure 12: Bayonet-type quick connect gas tap no longer permitted in a number of jurisdictions [49]

Any laboratory refit or renovation should include replacement of bayonet-type outlets with a suitable turret tap.


Figure 13: The standard double turret tap[50]

The standard in-line turret tap has a lever control that is at right angles to the gas flow when closed. A 90^{o} turn opens the gas line. These taps can be turned on accidentally. The position of the lever is visible from a distance, so one can tell whether the tap is ON or OFF.


Figure 14: Lift-and-turn turret[51]

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48 Science ASSIST. 2014. *ASSIST Information Sheet: School science laboratory gas fitting requirements*, Science ASSIST website, http://assist.asta.edu.au/sites/assist.asta.edu.au/files/AIS%20School%20science%20laboratory%20gas%20fitting%20requirements.pdf (August 2014)

49 Images: (L) http://www.hoses.co.uk/ (R) Qld Dept of Natural Resources and Mines website https://www.dnrm.qld.gov.au

50 Images:(L) http://www.ecvv.com/product/2608959.html (R) http://www.westlab.com.au/

The lift-and-turn turret tap has a similar 90º action but the knob or lever must be lifted slightly before it is turned to the ON position. This prevents the gas from being turned on accidentally, but in the case of the knob fitting the position of the tap is not apparent from a distance.

The type that allows the ON or OFF position to be apparent from a distance is preferred.

6.5.1.2 Other gas appliances

Stand-alone gas space heaters may be common in school classrooms but they are not appropriate for either teaching laboratories or preparation laboratories. The naked heating flame and pilot light create a source of ignition for flammable vapours.

In the preparation laboratory, a gas ring or bench-top gas burner is a useful addition for heating large vessels such as pressure cookers/sterilisers that are too large for a normal Bunsen burner on a tripod stand. The gas flame provides a heat source that can be adjusted more quickly than an electric hot plate.

6.6 Electricity

Careful planning and audit of mains electricity supply throughout the science precinct will determine the optimum number, distribution and placement of general-purpose 240v AC outlets (GPOs) and switch controls for lights and other devices[52].

School science laboratories are much tougher on fixtures and fittings than a domestic or office environment. Less expensive ‘budget’ electrical switches and GPOs will not last long under the treatment meted out by students and contact with corrosive chemicals and solvents. Failure of an electrical fitting is not only costly but can also be dangerous.

In the teaching laboratory, each student workbench will need a double GPO for each practical group. There are various devices used in practical classes, e.g. hot plates, microscopes, electrophoresis equipment, AC/DC adapters etc. that require mains electricity.

The other benches in the classroom will need GPOs to service shared equipment, e.g. water baths, electronic balances, bench ovens or incubators.

The teachers’ demonstration bench will need similar GPOs to the student workstations, but also additional outlets for specialised AV equipment.

Office areas need sufficient GPOs for computers, printers, scanners, laminators etc.

Adequate provision of GPOs will minimise the need to use extension cords, and multi-outlet power boards that can cause electrical and physical hazards.

The electricity supply to the teaching laboratory outlets should be connected through separate circuits for different sections of the laboratory, e.g. the teacher demonstration bench, the side benches, and smaller blocks of student workstations. Some equipment such as fume cupboards[53], refrigerators, freezers, aquariums and ongoing laboratory experiments may need a dedicated supply of power that is independent of other circuit controls.

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[51] Images: (L) http://www.labsolni.co.uk/ (R) http://shawscientific.com/

[52] Standards Australia Ltd/Standards New Zealand. 2007. *AS/NZS 3000:2007 Electrical installations (known as the Australian/New Zealand Wiring Rules)*, Standards Australia: Sydney.

[53] See Section 5.4, p. 30.

Sensitive electronic equipment such as computers, and interactive screens may need to have a circuit with surge protection.

6.6.1 Location of power points

Mains GPOs are best positioned away from sinks and water taps, and designed to prevent the entry of water. They should be mounted at least 300 mm above the surface of the workbench or floor; on a service bollard or wall mounted. A physical barrier such as a reorienting the GPO, or a hood will provide some protection if the minimum 300 mm separation cannot be achieved.

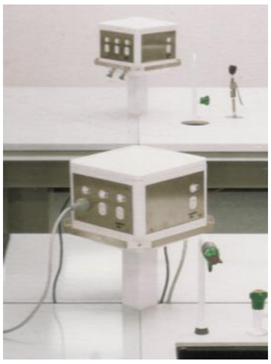

Figure 15: (L) An elevated service bollard, (C) a GPO orientated away from the water source, (R) a hooded GPO[54]

Even GPOs that are in dry areas need some height above the surface to allow for the depth of the integrated low voltage power adapters (left) that are used with many devices

6.6.2 Low voltage power supply

Portable low-voltage bench top power supplies typically supply 2–12V at max 5A. AC or DC. They are more practicable that a fixed built in system.

- **Economy**: Class sets of 2–12V AC/DC power supplies will be less expensive than installing and maintaining a built-in system in several teaching laboratories.
- **Flexibility**: More teaching laboratories can be used for low-voltage practical work because the portable power supplies can be moved from room to room as required.
- **Output control**: Each practical group can select their required output voltage on the power supply independent of other groups.
- **Maintenance**: Portable Appliance Testing (PAT) will identify a faulty power supply that can be taken out of service while all the others remain in service. A failure of a central, built-in system would render all the outlets unusable until specialist repair is completed.
- **Maximum output**: Portable supplies can be selected to deliver safely a range of either AC or DC outputs in voltages up to 500 V, and currents from 50mA to 5A. Central systems typically share the current between 12–15 outlets at max 2 V per outlet.

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[54] Images: (L) http://www.spacelab.com.au/ (C) http://www.hellopro.co.uk (R) http://www.radioparts.com.au/

- **Vandalism**: Both portable and central low voltage delivery systems could be the target of vandals. The central system is present in the teaching laboratory and exposed to malicious damage and tampering all the time. The portable units can be stored securely out of class-time.

6.7 Lighting

The design of illumination systems—combining daylight and artificial lighting—will have an impact on performance and comfort, and the response of the people using the environment. The design and orientation of the building should address the use of natural light and energy conservation.

Optimum levels of light will vary with the tasks being undertaken. Other factors, such as light colour, temperature and distribution will also affect a person's visual performance:

Type of activity	Range of illuminance (lux)
Spaces where visual tasks are only performed occasionally, e.g. corridors and foyers	100–200 general area lighting
Visual tasks in areas with high contrast, reading printed material, low precision manual work, e.g. offices,	200–500 Illuminance on the task
Visual tasks in medium contrast, reading hand writing, small print, medium precision work; general laboratory spaces, and storerooms	500–1000 Illuminance on the tasks
Visual tasks with low contrast or very small size, in the laboratory, chemical labels, digital balance displays, graduation marks on volumetric glassware.	1000–2000 Illuminance on the tasks.
Visual tasks with low contrast and very small size over a prolonged period or repetitive, e.g. in the laboratory fine; assembly or repair of delicate equipment, biological dissections, loading gels for electrophoresis	2000–5000 Illuminance on the task

Figure 16 Lighting levels [55]

6.8 Natural light

Natural light can add to the positive ambience of the working environment when it provides gentle uniform illumination. Chemicals and laboratory equipment can deteriorate under direct intense sunlight. Direct sunlight will create unwanted glare and reflections that impair visual performance, and interfere with computer screens and other visual display equipment.

6.8.1 Artificial light

Daylight entering the building will be subject to daily, climatic, and seasonal variations in temperature, direction, intensity and diffusion.

These variations can be addressed by the use of artificial light. Choice of the type, position and orientation of light fittings is important for successful integration of natural and artificial light.

[55] Sanders and McCormick, op. cit.

Artificial lighting may also create unwanted glare and reflections, and interfere with display screens. Lighting in those areas should be on its own circuit and fitted with dimmer switches.

6.9 Ventilation

The Building Code of Australia covers the general requirements for ventilation of school buildings. In addition, ventilation systems in laboratories must provide air quality to maintain well being and comfort of the occupants, remove airborne contaminants, flammable or corrosive substances that can cause damage to fixtures and fittings. [56]

6.9.1 Natural, mechanical or local extraction

A school science precinct can combine natural ventilation through fixed vents, operable doors and windows, and mechanical systems. Any ventilation system may add to the ambient noise level, and should be assessed for the affect it may have on learning and laboratory operations.

Natural ventilation:

- Vent openings have an opening area not less that 10% of the floor area, located to create cross flow for effective exchange of air.
- Control of temperature and humidity is maintained.
- Fume cupboard performance should not be compromised by flow of air from natural ventilation across the face of the cupboard.
- Natural ventilation is not the primary source of control of airborne contaminants.
- Laboratories that are subject to Physical Containment (PC) requirements for microbiological agents should have stainless steel mesh screens on exterior operable windows and air vents and are recommended on all operable windows.
- The airflow from the laboratory should be kept away from other classrooms, laboratories and non-laboratory areas.
- Partitions between a laboratory and other areas must have no ventilation opening other than access doors.

Mechanical ventilation (augmented by natural ventilation systems):

- Provide exhaust ventilation to address the particular processes that are carried out in the laboratory.
- Control dispersion or accumulation of airborne contaminants.
- Prevent recirculation of air from laboratories into non-laboratory areas.
- Remove airborne contaminants from the laboratory environment.
- Exhaust air discharges located to prevent contaminated air being drawn into intake vents or other open windows/doors creating hazardous exposure for people, animals or the environment.
- Requires an adequate source of ‘make-up’ or replacement air to prevent the creation of a pressure gradient within the room that reduces the efficacy of the ventilation systems. [57]

Ceiling mounted exhaust fans, similar for domestic kitchen or bathroom use, are often installed in teaching laboratories, preparation laboratories, and chemical stores. While

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[56] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010*, ibid.

[57] Standards Australia Ltd/Standards New Zealand. 2014. *AS/NZS 2243.8:2014 Fume cupboards,* Standards Australia: Sydney, Section 3, pp. 18–19.

these have some features in common with industrial systems they are not adequate or sufficiently robust to meet the need of a school laboratory.

Ventilation is most effective when airborne contaminants are extracted at their source before they have dispersed into the laboratory environment.

Local exhaust ventilation systems do not replace fume cupboards.

6.9.2 Emergency

In the case of a major incident that releases large amounts of noxious or hazardous vapours or airborne contaminants, the usual mechanical ventilation systems will be inadequate. The first duty of the school is to protect the occupants by initiating emergency evacuation procedures.

6.9.3 Fume cupboards

Fumes cupboards are essential items in a school science suite. They are essential for laboratory technicians for preparation of reagents and dispensing of chemicals, and important for senior chemistry practical classes. However, they are a major capital expense. Their effectiveness depends on careful planning of the space, furniture and fixtures that surround them[58].

Two different types of fume cupboard are available: ducted fume cupboards, either single or double sided, and recirculating fume cabinets. While they have some common features, there are important distinctions in the applications for which they are designed.

6.9.3.1 Ducted fume cupboards:

Ducted fume cupboards are fixed, installed into a workbench area with power, gas, water and waste outlet services connected permanently.

The Australian Standard on fume cupboards[59] describes the features, and testing regimes required.

- Outlets for reticulated services, e.g. gas and water must be mounted on the inside surface.
- Electrical service outlets, e.g. switches and GPOs are sources of ignition. They must be positioned outside the fume cupboards chamber, and protected by a RCD device.
- The fume cupboards must not be included in any central power management systems, such any other laboratory emergency cut-off switch.
- All service controls must be mounted outside the fume cupboard chamber, and not operable unless the extraction fan is operating.
- Light level within the chamber not less than 400 lx.
- The base of the chamber will contain spills.
- The sash must be transparent, made from materials that resist corrosive or flammable substances. Its maximum and minimum opening shall be set with a stop.
- Baffles fitted to facilitate effective capture of the fumes.
- Uniform face velocity, average 0.5m/s with variations of not more than 20%
- Provision of a source of *make-up* air to maintain optimum pressure gradients and airflow.

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[58] ibid., pp. 18–19.

[59] ibid., Appendix F, p. 54–56.

- Minimising air turbulence.
- Annual testing regimes.

6.9.3.2 Ducted, double-sided fume cupboards[60]

Ducted, double-sided fume cupboards are available to install between two laboratories. Such sharing between teaching laboratories may be a cost-saving measure but it creates added hazards and unnecessary distractions for teachers and students in the teaching laboratory not using it. If installed the double-sided fume cupboard must have duplicate controls and emergency isolators on each side.

Effective airflow in double sided fume cupboards can be compromised if there is a pressure differential between the rooms that share the fume cupboard.

Shared fume cupboards are not a preferred option for preparation laboratories. The preparation laboratory should have its own fume cupboard to handle sources of hazardous vapours during preparation operations. This will avoid interruption of adjoining classes and exposure of the students and teacher to hazardous preparation procedures.

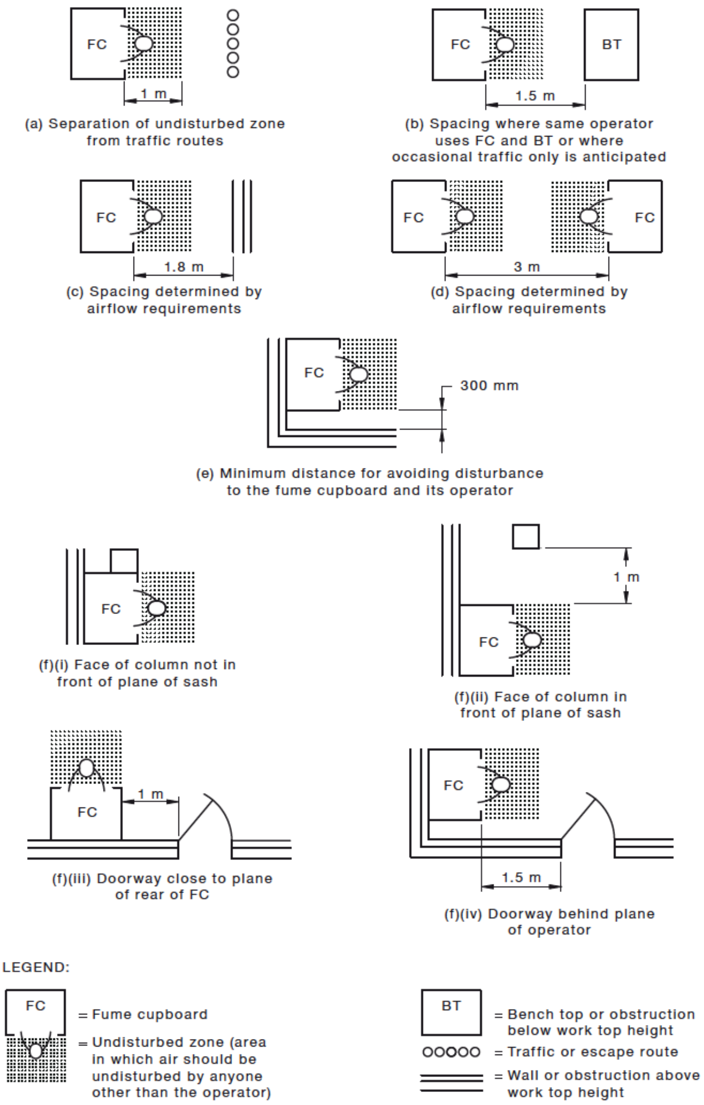

Figure 17: AS/NZS 2243.8:2014 Siting a fume cupboard[61]

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[60] ibid., Appendix D.10, p. 51.

6.9.3.3 Recirculating fume cabinets [62] [63]

Recirculating fume cabinets have numerous limitations and are ***not recommended for school science laboratories***. For more detailed information see also Science ASSIST Information Sheet *Recirculating fume cabinets*.[64]

Recirculating fume cabinets are promoted as an alternative to built-in ducted fume cupboards because they are portable, cheaper, and easier to install because they don't need exhaust ducting.

They draw air into the cabinet and exhaust it with any contaminants through a filtration and absorption system, returning the filtered air back into the laboratory atmosphere.

There are many limitations to this filtration system that are not recommended for school science laboratories.

- Suitable for only a narrow range of substances.
- Suitable only for small quantities of low risk chemicals.
- Filters must be selected for compatibility with specific substances, and are not interchangeable.
- Not suitable for highly toxic, flammable or corrosive substances or for more than 50 mL corrosive fumes in one day.
- Not suitable for organic solvents with low boiling points i.e. < 75 ^oC.
- Atmospheric conditions such temperature and humidity can affect the filter operation.
- Replacement and disposal of the depleted filters is hazardous.
- They incur lower capital costs but higher recurrent maintenance costs.

The initial capital cost of the fume cupboard should not be the sole consideration when deciding between a ducted fume cupboard and a recirculating cabinet. The effectiveness in managing the chemical hazards, and the longer-term recurrent costs and maintenance hazards should be the first factors to be considered.

6.9.4 Chemical storage areas: General requirements

Chemical storerooms need security and protection against heat and direct sunlight so natural ventilation alone via operable external doors and windows is not practicable.

The chemical storeroom must have its own discrete mechanical ventilation system with external vents to exhaust vapours and refresh the air at the required rate.[65] The system shall have a capacity of 0.3 m^3 per m^2 of floor space per minute, or 5 m^3 per minute, whichever is greater.[66]

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[61] Standards Australia Ltd/Standards New Zealand. 2014. *AS/NZS 2243.8:2014 Fume cupboards,* Standards Australia: Sydney, Section 4.1 Figure 1, p. 29. Reproduced with permission from SAI Global Ltd under Licence 1407-c117

[62] Standards Australia Ltd/Standards New Zealand. 2009. *AS/NZ 2243.9:2009 Safety in laboratories Part 9 Recirculating fume cabinets*, Standards Australia: Sydney.

[63] CLEAPSS 2014, *G9 Fume Cupboards in Schools,* Revision of DfEE Building Bulletin 88, Chapter 2.3 Recirculatory filtration fume cupboards, p.9, CLEAPPS website, http://www.cleapss.org.uk/attachments/article/0/G9-1.pdf?Secondary/Science/Guides/

[64] Science ASSIST. 2015. *ASSIST Information sheet: Recirculating fume cabinets*, Science ASSIST website, https://assist.asta.edu.au/sites/assist.asta.edu.au/files/AIS%20-%20Recirculating%20fume%20cabinets.pdf

[65] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010. op.cit,* Section 5.7, p. 27.

[66] Standards Australia Ltd/Standards New Zealand. 2004. *AS/NZ 2243.10:2004. op.cit.*, Section 5.4.4, p. 26.

The ventilation system should have the capacity to operate continuously—or for extended periods by an automatic timing mechanism—not only during school hours or when the light is switched on. Even with the best management of the containers in the chemical store some chemical fumes will be emitted continuously—not only when a person enters.

The fan needs to be suitable for the hazards of the chemical store. This means that the fan, fan blades and associated components have minimal potential to create sparks in order to meet the requirements of AS 1940—2004 *Storage and Handling of Flammable and Combustible substances*. Domestic ceiling fans are not suitable.

There must be no sources of ignition within the chemical store. Switching devices for ventilation fans or lights must be outside the storeroom, e.g. a switch just outside the entrance door.

Expert advice should be sought to determine the most suitable mechanical ventilation system for the size, shape and location of the store. The Victorian Department of Education and Training *Guidance Sheet 1: Chemical Storage*[67] has the following guidelines:

'Where quantities of chemicals being stored exceed minor storage, mechanical ventilation is required. If installed, mechanical ventilation should meet the following requirements:

- Separate fresh air supply and exhaust ducts shall be installed within the room on opposite walls at a distance between them of no more than 5 m.
- If a single fan system is installed, the fan should be in the exhaust duct.
- If the ventilation system incorporates fans on both the supply and exhaust `ducts, the capacity of the fans shall be adjusted so that the fan on the exhaust duct is greater.
- The system should be capable of exhausting 0.3 m^3 per m^2 of floor area per minute or 5 m^3 per minute, whichever is greater, and the air velocity at the air supply outlet shall exceed 300 m per minute.
- Any intake or exhaust duct shall terminate in open air at least 2 m from any opening into a building, or 4 m from the outlet of any chimney or flue and 3 m above the ground.
- The system shall be designed so that it operates either continuously or whenever work is being carried out in the area or whenever a person is in the area.'

Separate venting of chemical storage cabinets [68] [69]is not mandatory unless the risk of hazardous vapours cannot be controlled by normal laboratory housekeeping methods such as tightening the caps of containers, and cleaning up any drips or residues within the cabinet. A risk assessment of the storeroom may find that it is sufficient to install effective mechanical ventilation of the entire storeroom.

Standards Australia. 2004. *AS 1940—2004. op.cit*, Section 4.5.5, p. 47.

[67] Victorian Department of Education and Training. n.d. *Guidance Sheet 1 : Chemical Storage*, p5, Victorian DET website, http://www.education.vic.gov.au/school/principals/management/Pages/chemicalmgt.aspx (Accessed August 2016) Quoted with permission.

[68] Standards Australia Ltd/Standards New Zealand. 2004. *AS/NZ 2243.10:2004. op.cit.*, Section 3.3.4, pp. 15–16.

[69] Standards Australia. 2004*. AS 1940—2004. op.cit.*, Section 4.9.5, p. 53.

Chemical cabinets such as those approved for segregation of incompatible chemicals are fitted with two vent outlets—an inlet at the top of the cabinet and an outlet at the bottom. Both must be kept closed unless external ducting is installed.

If venting is required then both vents must be ducted to the outside. The vent ducting must be resistance to fire and attack from the chemicals themselves.

7 Surfaces, furniture and fittings[70]

7.1 Basic requirements

All the physical components of the science laboratory precinct—fixtures, furniture, procedures and people—must coalesce to create a working and learning environment that is both aesthetically pleasing and functional. With careful design these two principles need not be mutually exclusive.

7.2 Surface features

7.2.1 Wall coverings

Walls in all laboratories and storerooms must have surface coatings that are impervious, resistant to chemicals, smooth and easy to clean[71].

Porous surfaces will allow moisture, chemicals and biological contaminants from fumes or splashed material to be absorbed and cause deterioration of the surface. Textured surfaces such as those found in some wallpaper products have minute indentations that can harbour chemical particles and microorganisms. Such surfaces are not easily cleaned or disinfected.

The walls of many school teaching laboratories are plasterboard or composite fibreboard, which are not naturally impervious. These can be made more resilient if the sheets are securely joined, and the surface prepared and coated with a good quality washable satin or semi-gloss paint. Such a finish is sufficiently durable and relatively inexpensive to refurbish when necessary.

Walls in wet areas such as sinks can be finished with ceramic tiles .The grouting between the ceramic tiles can deteriorate and must be repaired to maintain the protective finish over the life of the tiles. Glass splash-backs or sheet PVC wall cladding are alternatives to ceramic tiles. They are watertight, need little maintenance, and the seamless finish resists contamination by chemicals or microorganisms. These options have higher capital costs than plaster or fibreboard but are less susceptible to the effects of moisture, and so the ongoing recurrent costs are lower.

Wall colour and pattern can affect the amount of ambient light in the laboratory. Bright white can cause unwanted glare and reflections but a subtle pale to medium tone will reflect and diffuse the light more evenly. Display space on the laboratory walls can be used to add educational features and colour but the display materials should be protected from contact with heat and flame, or water and other splashed materials.

7.2.2 Ceiling materials

Similarly the ceiling materials must be smooth and non-absorbent, and finished a light colour to maximize the reflection and diffusion of light. This will enhance natural light and also reduce the amount of artificial lights required.

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[70] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010. op.cit.,* Section 2.4, p. 15.

[71]ibid*.,* Section 2.6 Walls, p. 16.

Acoustic ceiling tiles are still common in teaching laboratories. They can address some undesirable acoustic properties of a large space but they may deteriorate in contact with moisture or chemicals, or break down as they age.

When renovating an existing structure the ceiling tiles must be inspected for damage and the presence of asbestos which was used in acoustic materials in earlier years. The state and territory authorities have regulations covering the testing, treatment or removal of Asbestos materials.

7.2.3 Flooring[72, 73]

Selection of flooring materials and finishes must consider the following factors.

- Slip-resistant, even when wet, throughout lifetime of floor
- Impervious surface, grout-free
- Coves to wall joints for rounded corners
- Resilient surface, comfortable underfoot, contributes to reduce ambient noise levels
- Resistance to corrosive chemicals and solvents
- Cleaning and maintenance—short and long term
- Fire and heat resistance
- Static electricity
- Appearance
- Cost.

When designing a brand new facility consider whether the flooring could be laid first before fixed furniture and equipment. Refits or renovations of existing facilities may not have the same options.

7.2.3.1 Material and coverage

Heavy-duty chemical resistant vinyl is the recommended flooring for science laboratories. A pre-finished sheet vinyl or equivalent can meet all the necessary criteria for laboratory floor coverings. It should have welded joins and taken 150 mm up the walls and where there are solid fixtures such as support columns or storage units at floor level. Where workbenches that are floor-mounted on pillars are fitted with kickboards, the floor covering must also be taken up the kickboard to contain spills. Pre-finished sheet vinyl is an attractive option for schools because it both inexpensive to install and to maintain, and has a wide range of colours and designs available.

The floor covering should be smooth and seamless so that spills are contained, and dirt does not collect at the wall/floor interface.

The floor covering system—including the underlay—must also be sufficiently durable to withstand the daily contact with chair or stool legs, scuffing from shoes, and the inevitable damage from students, who rock or spin their chairs on one leg or slide school bags across the floor. From time to time there may be hot materials dropped, sharp edges of equipment, chemicals that stain, damage or react with the surface.

Many flooring materials and finishes that are desirable aesthetically in homes or office environments are not suitable for laboratories.

[72] Griffin, op. cit. p 36.

[73] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010. op.cit,. Section 2.5 pp. 15–16.*

- **Ceramic, porcelain or quarry tiles** are very hard and noisy and uncomfortable for standing tasks. Dropped glassware and other fragile equipment are more likely to break. The grouting required is not impervious to chemical attack. Unless the tile surface is sealed, staining and other damage will result from contact with chemicals. They have lower slip-resistance unless they are specially treated.
- Similarly **polished concrete** is hard, noisy and uncomfortable underfoot. It will need very effective sealants to prevent damage from water and corrosive chemicals. Whether sealed or not, unless specifically treated it is slippery when wet. Unsealed concrete will produce dust which itself is very abrasive and damaging to other fittings and sensitive equipment.
- **Timber floors**. Both floorboards and composite particleboard have better comfort and acoustic properties, but worse resistance to water and chemicals. All exposed surfaces and edges must be sealed to protect the timber but the finish must be slip-resistant.
- **Rubber sheet flooring** with large disc or ridge patterns in relief can be resilient, impervious and slip resistant but the coarse relief pattern can collect dirt from foot traffic, and also be too rough for the smooth passage of trolleys across the floor, and uneven for shoes with high heels. (Fig. 20)
- **Carpet**. Few carpet products can meet all the criteria for laboratory flooring. Even in dry areas, carpet can generate static electricity that may be damaging to sensitive electronic equipment or a source of ignition for flammable substances. While the acoustic and comfort properties are useful in a classroom the need for durability, water and chemical resistance, and ease of cleaning and maintenance to remove chemical and biohazard residues, renders carpet unsuitable for laboratories.
- **Composite material**, which is laid as a loose aggregate of granules of rubber or synthetics in an epoxy base, is useful for levelling an uneven surface. It can be laid with an acoustic underlay, and combines slip and chemical resistance with resilience to abuse. The advantage is that damaged areas a can be repaired or replaced as needed without affecting the entire floor area.

7.2.3.2 Floor surface texture

Slip resistance properties need not depend on a rough, grit-filled surface, or one with high relief patterns. These highly textured finishes are not suitable because they are very effective at collecting and holding dirt from the soles of shoes. Mechanical scrubbers will be needed to clean the floor.

A good quality pre-finished smooth sheet vinyl will maintain its durability and slip-resistance if cleaned and maintained according to the manufacturer’s specifications.

Figure 18: Sheet vinyl with welded joins[74]

Figure 19: A rough grit-filled surface collects dirt up to 150 mm

Figure 20: Sheet rubber with a high-relief texture is too uneven for trolleys and shoes with heels[75]

7.2.3.3 Colours and patterns

The choice of colours and patterns of the flooring can enhance the aesthetic features of the room design but the choice must include consideration of human factors such as the effect of ambient light and visual acuity.

A pale, subtle colour in a matt finish will reflect and diffuse light more effectively than a dark glossy finish. Dark, gloss finishes with bold patterns can mask spills of water or chemicals, create distracting reflections or render dropped objects hard to find.

7.2.4 Laboratory benches

Most school science laboratory functions are performed on a workbench. The design and placement of the workbenches will depend on the operations that are being undertaken.

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74 Image: http://www.oddsnends4u.com/

75 Image: http://www.drfrubberflooring.com/

Standing height benches are more suitable for chemistry, earth science and physical science. Life science activities or tasks that require close attention, or take extended periods of time, such as inoculation of microbiological culture plates, microscope work, or repair of delicate equipment may require the operator to be seated. In that case sufficient 'knee room' must be provided under the bench. Knees require a horizontal clearance distance from the edge of the bench or desktop.[76]

7.2.4.1 Height and depth

Much laboratory bench work is done while the operator is standing. The standing posture is safer when working with chemicals and other 'wet' operations. A person who is standing at a bench is able to move away more quickly from a spill or other hazardous event at the bench such as fire or shattered glass. The recommended height of a laboratory bench for adults when standing is 900 mm. When the operator is seated the recommended bench height is 700–750mm[77]. For both standing and seated tasks the bench height may need to be modified if the tasks require the operator to use a higher degree of precision or dexterity.

The range of ages and sizes of the school children using the benches will determine the optimum height, but it may be difficult to design a fixed bench top with services installed that accommodates students of all ages and year levels.

The dimensions of bench-mounted laboratory equipment such as ovens, water baths, autoclaves and dishwashers will determine the height and depth of those benches.

The depth of the bench is also important. Laboratory equipment may need a minimum depth but for personnel the bench tops should be no deeper across than a person can comfortably reach. The normal adult reach is about 400 mm, and the maximum extended reach is about 500 mm.[78]

7.2.5 Shelving and under bench storage and cupboards

Laboratory supplies and equipment are often stored in under bench cupboards or on shelves over the back of the workbench. While this storage area is popular they are not the most efficient or convenient options.

Reaching over and across equipment and reagents on a bench top to access items on the shelving behind, or bending down to reach into low cupboards or shelves under the bench is hazardous for laboratory users. The use of full height cabinets is safer and more efficient.

If overhead cupboards are installed, then they should be mounted to a minimum of 600 mm above bench height and the underside of the cabinet should have a heat treatment above gas outlets to take into consideration the use of Bunsen burners.

7.2.6 Spacing

Laboratory workbenches must be located with enough space around the bench to allow cupboard doors to be opened fully, and free movement of personnel, and trolleys between and around the laboratory.

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[76] WorkSafe Victoria. 2006. *Officewise—a Guide to Health and Safety in the Office*, 5th Edn, pp 37–38, Worksafe Victoria website, http://www.worksafe.vic.gov.au/forms-and-publications/forms-and-publications/officewise-a-guide-to-health-and-safety-in-the-office

[77] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010.* op. cit., Appendix A5, p 49.

[78] Sanders and McCormack, op. cit.

AS/NZS 2982:2010 *Laboratory Design and Construction*[79] has the following minimum spacing requirements.

- Where the worker stands at a bench on one side of an aisle opposite a wall or other fixtures, with no through traffic – Minimum distance of 1000 mm
- Where the worker stands at a bench on one side of an aisle opposite a wall or other fixtures, with some through traffic – Minimum distance of 1200 mm
- Where the workers stand at benches on both sides of an aisle with no through traffic – Minimum distance of 1400 mm.
- Where the workers stand at benches on both sides of an aisle with some through traffic – Minimum distance of 1800 mm.

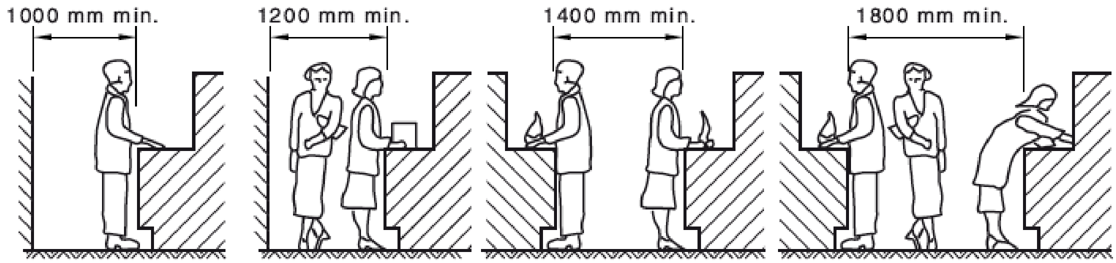

Figure 21: *AS/NZS 2982:2010* Requirements for aisle widths[80]

The needs of a large class may mean that aisles should be widened to provide safe access and egress.

7.2.7 Surface texture, colours and patterns

Textured and patterned surfaces may be suitable for household kitchens but not for laboratories. Textured surfaces harbour dirt, chemical residues and bacteria. A textured, hard surface is more slippery than a smooth one. A glass flask or beaker will slide more easily on a textured surface. The contact surface area between the bench and flat-bottomed glassware is less for a textured surface. This means less friction between them. The diagram below shows an exaggerated view of the difference between a smooth and a textured surface.

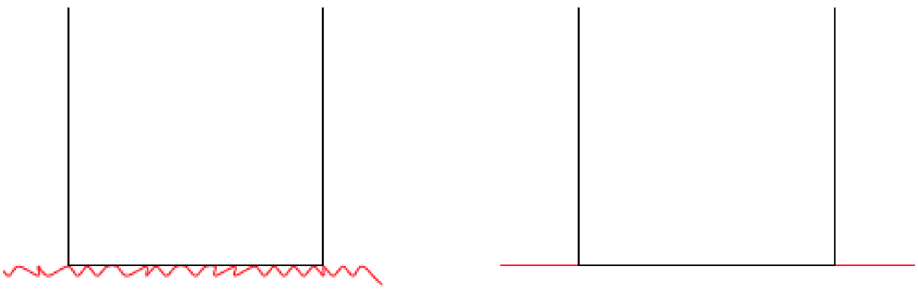

Figure 22: An exaggerated view of the contact area between a glass beaker and a textured surface versus a smooth matt surface.

Bench top surfaces should have a smooth, matt finish with little or no pattern in a light to medium tone. Dark colours, and boldly-patterned surfaces may not show dirt and

[79] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010.* op. cit., p. 17.
[80] Standards Australia Ltd/Standards New Zealand. 2010. *AS/NZS 2982:2010.* op. cit., Figure 2.1, p. 18

damage so much as plain ones, but they will also mask chemical spills, and make pieces of broken glass and small items hard to find. Dark colours and bold patterns may not show stains and damage as much as do lighter plain finishes but they will also mask chemical spills and make small items such as pieces of broken glass much harder to locate.

7.2.8 Materials

The bench top finish must be:

- smooth with a matt finish and without a coarse texture.
- resistant to heat and flame
- resistant to the chemicals used in the laboratory
- scratch resistant
- easy to clean
- free from joints so far as possible. Joints must be sealed to prevent seepage of spills into the space beneath. Where ends of the bench meet and end at a wall the bench top finish shall continue up the wall to form a splash back.

There are many bench top materials and coatings that can meet these criteria.

- Good quality laminate over composite fibreboard with minimal joints that are well sealed. This will be resistant to most chemicals, and to scratching. However, it will suffer damage from aggressive solvents, concentrated acids, and hot equipment and naked flames. It is not easily repaired in patches so the entire bench top may need to be replaced.
- Solid surface sheeting. It uses a jointing material that colour matches the sheeting it conceals the joints and can repair scratches holes or cracks. It is easily cleaned with a detergent or mild household abrasive.
- A compact laminate that is hardwearing and chemical resistant. It is designed specifically for laboratories. It is also repairable.

Unsuitable materials for laboratory bench top applications are:

- stainless steel
  - Very hard, and cold to the touch. Glassware dropped on this will break more easily. It is not resistant to common laboratory chemicals.
  - Dilute acids and alkalis, and some metal salt solutions will leave corroded areas.
  - Conducts electricity, so that practical activities involving electric circuits will need an insulating mat.
  - Easily scratched, and difficult to keep looking clean.
- Sheet vinyl

  Some school laboratories, especially science demountable units often have benches finished with a vinyl sheet similar to the floor covering.

  - Not heat or scratch resistant.
  - The polyurethane finish will soon degrade and the surface will deteriorate in contact with aggressive solvents or concentrated acids.
  - Heat and chemical attack will evolve toxic vinyl chloride fumes.
  - Vinyl is difficult to clean. Abrasive cleaners and graffiti remover will damage the surface.

    - Damaged areas must be removed and replaced.
- Timber finishes including sheet ply, laminate and composite particleboard.
    - A timber surface is not waterproof or resistant to chemicals, heat or flame.
    - Sealants may improve waterproofing properties but it will remain susceptible to other damage.

7.3 Desks: staff members and students

Laboratory staff and science teachers need to have their own desks in an office adjoining the preparation laboratory and science teaching laboratories. Teachers may need access to stored class documents and resources, and to consult laboratory staff about science practical classes. Laboratory technicians need an area for general administration tasks such as planning, sourcing and ordering supplies, safety information, and record keeping that is close to the preparation and storerooms.

Students may need to have access to private study or 'breakout' areas for research or written work that are not part of the science-teaching laboratory.

7.3.1 Location.

The teaching laboratories, preparation laboratories and storerooms have specific needs for ventilation, heating, cooling and lighting that are different to the needs of an office or study area. A laboratory exhaust ventilation system, ovens and sterilisers can interfere with office heating or cooling systems. The noise generated by laboratory equipment and operations such as dishwashing, grinding, magnetic stirrers, or fume cupboards, etc. can disturb those working at their desks or undertaking private study.

Staff offices for teachers should be located close to the science preparation and teaching laboratories for ease of access and communication. However, it is essential that laboratory technicians' office areas be separated from have a connecting door into the preparation laboratory—preferably with a window to see into the laboratory from the office area. Ventilation, heating, and cooling systems for the laboratory should be separated from the office system.

7.3.2 Desk height and laboratory seating

Normal desk height for writing or office tasks is 610–760 mm. Workbenches for standing tasks at height 900 mm can also be used for desk-based tasks provided appropriate seating and knee room is provided.

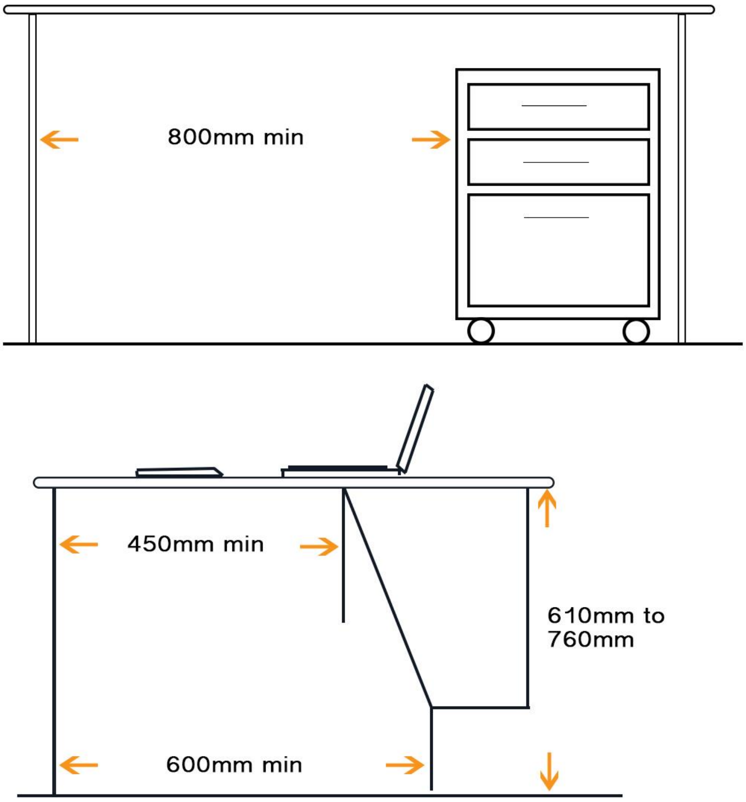

Figure 23: Knee room required when seated[81]

Wherever possible, workstations—desk and chairs—that are used for extended periods should be adjustable to suit the users. Freestanding desks with legs that can be adjusted are preferable to built-in fixed units but in many cases only fixed desk units are provided. Adjustable seating, whatever the desk height, is essential.

Office chairs that have adjustable features such as seat height, lumbar support, arm rests, and seat and back tilt, and headrests are usually available for staff members. Student seating in the teaching laboratory is often poorly designed for its use.

Students are seated in class for long periods so the seating must have the same comfort and ergonomic features as office chairs. They must also resist the accidental damage and intentional vandalism that will occur. Criteria for choosing student laboratory seating include:

- ergonomic design
- suitable for a range of student ages
- lightweight
- stackable
- low maintenance
- resistant to deliberate abuse.
- wide legs with a protective ferrule to protect the floor covering also provide skid resistance and reduce noise.

[81] Adapted from WorkSafe Victoria. 2006. *Officewise – A guide to health &safety in the office, Edn No. 5*, WorkSafe Victoria website, http://www.worksafe.vic.gov.au/__data/assets/pdf_file/0016/3634/Officewise_web.pdf , p. 39

Stools: all the above but also:

- height to fit under the bench for practical work
- footrests at the appropriate height integrated into the stool frame.

Figure 24 L: a tubular frame stool, R: a cantilever frame that can be hooked onto the bench, the skid base will not damage the floor surface.[82]

The standing posture is safer when working with chemicals and other 'wet' operations. A person who is standing at a bench is able to move away more quickly from a spill or other hazardous event at the bench such as dropped equipment, fire or shattered glass. In the teaching laboratory chairs and stools at the workbench can create clutter and trip hazards.

However, for some extended practical or preparation activities the person will need to sit or be supported. Sit/stand seats, or straddle stools enable the user to support their weight while maintaining a standing posture and height.

These options should be provided to laboratory staff for tasks that involve standing for extended periods.

7.4 Control of sunlight, glare and reflections

When designing a new science facility there are options for orientating the building, and the configuration of windows to optimize the use of natural light.

Control of sunlight on the building can have a profound effect on energy efficiency by reducing the need for artificial heating and cooling and artificial lighting.

Windows are a source of natural light and views of the outside that are aesthetically desirable. A minimum window area of 20% of the exterior wall is recommended. However, if the window area is too large, or if it faces north or west the heating effect during the summer months can be extreme, and lead to the need for artificial cooling and shading of the room from radiation and sun glare. Conversely north or west facing windows can enhance warming to the building in cooler climates.

In the case of refit or renovation of an existing science facility or when orientation options for a new building are limited the design of window openings, and the layout of the internal spaces together with the use of external window shutters, awnings or

[82] Images: (L) and (R) http://www.education-furniture.com/

louvers, or internal window shades or screens may be the only means to control the entry of direct sunlight and heat.

The layout of internal spaces should optimise the entry of daylight. Windows will allow daylight to penetrate only 3 m into a room so shaded skylights or clerestory windows[83] will be necessary to provide additional natural light.

The size and orientation of skylights and clerestory windows should be such that glare and overheating are limited, and the need for artificial light is minimised[84]. Daily and seasonal variations in the sunlight must also be considered. Where external windows and skylights can be opened they should be fitted with insect screens.

The whiteboards, projection screens and computer screens and glossy surfaces such as glass cupboard doors will be subject to unwanted glare and reflections in direct sunlight.

Control of daylight will be necessary for particular practical classes.

- Physics: the study of light and photonics may need complete or near complete block-out.
- Blinds: whether roller, vertical or venetian-style, a grey reflective sunward surface is more suitable than a black textile that will absorb heat.
- Loosely draped block-out curtains are not suitable in areas close to Bunsen burner outlets where naked flames will create a risk of the curtains catching fire.
- Both blinds and curtains are subject to inadvertent or deliberate damage by students. Control cords or wands must be easy to reach but not placed where students can be tempted to play with them. Loose cords can also be a hazard unless they are secured to the wall.
- Adding a 'boxing' arrangement where a lip is provided on the inside of the frame where the window covering is boxed in between the window and the timber (or other material) of the boxing. This provides two benefits in that the covering does not easily blow out over the bench and that it reduces the amount light that enters around the edges of the windows.
- Soft, absorbent textiles such as curtains and blinds are not suitable for microbiology laboratories that need to meet Physical Containment requirements for managing risk of contamination by microbes.

Natural and artificial lighting should be integrated to optimise the relative merits against energy costs.

7.5 Acoustic issues

Design of the school environs to segregate and separate inherently noisy features such as external road traffic, or Music and Performing Arts and Materials Technology departments from other areas will help to reduce unwanted elements of ambient noise.

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[83] Definition: Clerestory (pronounced *clear story*) is a high section of wall that contains windows above eye level.

[84] CHPS. 2002. 'Daylight and Fenestration Design', in *CHPS Best Practices Manual 2002*, pp.209–252, Lighting Associates website, http://www.lightingassociates.org/i/u/2127806/f/tech_sheets/Daylighting_and_Fenestration_design.pdf

The acoustic properties of a teaching laboratory depend on many factors. Balancing the need for the effective transmission of necessary sound such as the teacher's voice and audio teaching aids against the attenuation of extraneous noise is complex.

7.5.1 Techniques and materials to dampen extraneous noise

The properties of various surfaces, fixtures and furniture such as walls, windows, floors, and ceilings, cabinets, chairs and tables, and the shape, size and layout of the room will contribute to the acoustic qualities.

Hard flat surfaces such as glass, concrete, and ceramic tiles add to the reflection and reverberation of sound that in turn makes hearing difficult. Soft textured or irregularly shaped surfaces such as fabrics can absorb the sound and reduce reverberation.

It is necessary to consider how extraneous noise is generated. Noisy equipment such as dishwashers, fume cupboards, extraction fans in the laboratories, or ticker-timers and signal generators in physics cannot be eliminated; nor can other noise from the movement of tables and chairs and students.

In addition to using suitable sound attenuating or insulating materials to control noise, effective isolation of noisy equipment and processes, and the preventative maintenance of plant and equipment can improve the acoustic performance of the science precinct.

8 Managing the transition to the new facility

A science facility is a significant educational and financial asset to a school.

Whether the new facility is an entirely new science block or building, or renovation of an existing one the transition into the new facility requires skilled management to minimise disruption to science classes and other school operations.

8.1 Decommissioning: packing and storing equipment and materials

When planning to pack the equipment, materials and chemicals to move to the new facility the following points must be considered.

- How far will the goods be moved, e.g. to a new site or another building on the same site?
- Will the goods be used in the new facility immediately or stored for a period of time?

Professional, specialist removalists will be able to give advice about how to plan and execute the moving process efficiently.

If the new facility is on a new site or a significant distance away then the equipment and materials must be packed securely to prevent accidental damage during transport. Sufficient, suitable cartons and packing materials should be chosen to fit the items without cramming.

The whole science precinct should be packed room by room, and the cartons marked to identify the source room and nature of the contents, and the required destination.

Before they are collected for transport to the new facility or after delivery to the new site, the packages may need to be stored for a period of time. At the very least the temporary storage area must be protected from the weather and secured against theft or vandalism. The usual Workplace Health and Safety requirements for a safe workplace must still be applied.

Chemicals, perishable or fragile items must also be protected against extremes of temperature, humidity, and direct sunlight or vibration. The temporary storage of chemicals must meet the statutory requirements for separation and segregation, and maximum quantities.

8.1.1 Chemicals

State, territory and national authorities regulate the storage, handling and transport of dangerous goods such as the science chemicals. The packing and transport of the science chemicals carries significant risks such as release of hazardous substances, and contact between incompatible chemicals. A spill or other incident that releases hazardous substances into the vehicle or the surrounding area, could affect the driver, other people nearby or cause damage to property. Gas cylinders in particular need specialist handling to prevent accidents.

When packing the chemicals for transport the segregation and separation of incompatible substances, and the quantities must be considered. For example, some incompatible chemicals cannot be transported in the same vehicle so careful auditing of the content of packages and the vehicles is necessary.

8.2 Transport and unpacking

Professional, specialist moving companies will be able to give advice about the sort of packaging and loading in the transport vehicles that is required, and provide that packaging and the vehicle and drivers to undertake the move safely and legally.

While the school laboratory staff should be consulted about the packing and moving process no school personnel whether staff, students or parents should transport chemicals in their own car or in any vehicle that is not meant for the purpose. Unless specified in advance such an incident in a private vehicle may not be covered by the vehicles' accident or public liability insurance.

Efficient unpacking of the science paraphernalia requires a systematic approach. Each carton should be delivered to the appropriate area in the new facility, and unpacked—taking note of the condition of each item and documenting or photographing any damage for insurance purposes.

Once access to the building is possible, the unpacking process can begin even if the final detailing is still underway. There must be access to communications such as a telephone, adequate lighting, ventilation, utilities and emergency equipment available, and remaining building materials, tools and equipment must not impede movement through the building.

Chemicals in particular must be unpacked carefully in a well-ventilated, well-lit area with an adequate supply of potable water for washing in case of skin or eye contact, and suitable spills kits in case packages have been damaged. Personnel must wear protective clothing, gloves, and safety glasses and be ready to respond to any evidence of damaged packaging or spills.

Only personnel or contractors with training and experience in handling scientific equipment and chemicals should be involved in the unpacking process. If more personnel are required they must have appropriate induction into the necessary practices and be supervised closely.

8.3 Commissioning the new facility

The construction contract documentation will include the terms under which the facility can be finally handed over to the users. The building guarantee will cover faulty materials or workmanship in the event of any failure during the guarantee period. Documentation of all specifications, user and maintenance/repair manuals for all equipment, fixtures and fittings must be provided to the building owner. Statutory requirements for testing and maintenance regimes must also be initiated.

8.3.1 Audit and documentation of problems to be corrected

There will be a period—typically 60–90 days—during which the building elements, fittings and fixtures can be checked against their contracted specifications and any defects can be identified and redressed. During this period regular walk-through audits of the new facility are recommended, and the science staff should be vigilant to observe any incidental faults or failures and report them promptly.

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11 Appendix: The planning checklist

General	Reference
Sufficient laboratories to teach practical science and allow time for proper routine servicing.	2.1
A large enough prep room for the technicians to work, and to house immediately needed chemicals and equipment.	3.4
Sufficient other secure and accessible storage including a separate internal (i.e. within the building) chemical store.	3.5
Teaching laboratories and preparation laboratories on the same floor and at the same level with each readily accessible from the other.	2.4
A science staff room for lesson preparation, marking and staff meetings, equipped with tea and coffee-making facilities.	3.2
Mechanical ventilation for the all laboratories and chemical storage rooms.	6.9
Protection from solar gain for windows that face the sun.	2.4 6.7
Heat-sensitive, not smoke-sensitive fire alarms used in the science suite and corridor.	5.3
Sufficient fume cupboards to teach chemistry.	6.9.3
Sufficient black out to teach physics.	2.1
Compliance with Physical Containment (PC) level 1 to teach microbiology.	2.1
Walls in all laboratories and storerooms must have surface coatings that are impervious, resistant to chemicals, smooth and easy to clean.	7.2.1

Specific planning for teaching laboratories	
General	
Minimum floor area 100m^2 (more may be required depending upon laboratory design/layout)	3.3
Flooring: Heavy duty, chemical resistant pre-coated sheet vinyl	7.2.3
Walls: Durable, easily cleaned, painted	7.2.1
Ceiling: Smooth, impervious, with acoustic properties to reduce extraneous sound.	7.2.2
Doors: 2 internal and external door access outward opening Self-locking external doors, no key required to exit	5.2
Windows: operable, lockable (all laboratories keyed alike) and fitted with insect proof security screens	2.4.1.1
Lighting: Sufficient natural and artificial lighting with separate switch for dimming the lights over the whiteboard. Adjustable control of sunlight to windows and skylights.	6.7 6.8.1
Water supply: Backflow prevention for water to sinks where chemicals are used At least one sink supplied with hot water. Sinks to have 'goose neck' or pillar tap fittings. Potable water supplied to an AS4775 compliant eye-wash station	6.2
Waste water: Connected to pre-treatment, such as dilution pits, as required by local water authority Laboratory sinks not to be interconnected, each to have their own P or S trap Fume cupboard waste plumbing to be kept separate from all other sink and floor waste plumbing in the teaching laboratory and preparation areas.	6.4

Gas supply: Reticulated supply– either Natural gas, or bottled LPG in fixed bottle storage. Outlets shall be provided with a lockable isolating valve located on or adjacent to the teacher's bench. Fume cupboard supply on a separate supply to teaching laboratories	6.5
Electricity supply: An RCD electrical safety switch on the appropriate circuits All power to general purpose outlets for student use supplied through an emergency/master control circuit operated by a suitably labelled push-button, with key operated manual reset, located near the teacher's bench adjacent to the main gas isolating valves. Power is supplied to the following on a separate circuit: Fume cupboard Dedicated GPOs for purposes such as ICT equipment such as data projectors; interactive whiteboards; teachers computer and AV; cleaners use; aquariums or ongoing science experiments	6.6
Legible and durable signs signage for all safety shut-offs	5.4
Fire protection: equipment as required by fire emergency services	5.3

Workspaces and ICT	4.4
Provision for safe stowage of student coats and bags	3.1
A teacher demonstration bench with all utilities (water, gas, power, ICT, drawers, lockable cupboard)	3.5.1 4.4 6.2.1 6.6.1
Sufficient, well-distributed sinks, gas taps, electrical power points (GPOs), ICT connections. Generally a minimum of 10 student work stations	6.2 6.6
Sufficient space between workbenches and writing tables to allow safe circulation during practical classes.	3.3
Minimum bench space for each student 0.36 m^2	3.3
Minimum of one large double sink with provision for a draining rack and hot water supply	6.2.1
Separate sinks for hand washing	6.2.1
Provision for ICT and AV equipment for class demonstrations	4
Sufficient static or dynamic display boards	4.4
Sufficient space to park trolleys holding equipment and materials during the class.	7.2.6

Laboratory furniture	
Laboratory bench height for standing tasks 900 mm	7.2.4
Student stools/chairs to suit benches/desks	7.3
Work bench tops made from resilient material such as resin or solid laminate	7.2.8
Height adjustable bench, minimum width 1500 mm for wheelchair access, complete with a raised return to contain any chemical spill (to prevent spilling onto the person in the wheelchair) as well as good clearance underneath.	2.3.2
Lockable cupboards/display cupboards for secure storage of materials and other teaching resources. (Keyed alike)	3.5.1
Cupboard doors with 270° hinges for ease of access	3.5.3

Overhead storage/display cabinets to be mounted a minimum of 600 mm above bench height, to a maximum height of the top shelf to 1500 mm and the underside of the cabinet to have a heat treatment above gas outlets to take into consideration the use of Bunsen burners.	7.2.5

Preparation laboratories and storage rooms (if not included in teaching laboratories)	
Adequate space for all technical staff to work without interruption from other personnel.	3.1
A technicians' office space that is separated from the hazards of laboratory area, to be used for ordering stock, keeping inventory, printing, reference and communication resources, e.g. phone, and networked computer, and peripherals such as printer and scanner.	3.2
Separate direct access to the preparation laboratory that does not require travel through other areas such as classrooms, teaching laboratories, offices, or breakout rooms.	3.4
Sufficient space for trolleys holding materials for practical classes	3.4
Some workbenches at 650–750 mm for seated tasks and close work.	
At least one large sink with double drainer and rear mounted draining racks and hot and cold water supply	6.2.1
A refrigerator, freezer, and glass washing machine.	3.4
A lockable, ventilated chemical store with space for approved safety cabinets for dangerous goods.	3.5.4
Secure storage of gas cylinders out side the laboratory area.	6.5
A fully ducted single-sided fume cupboard to meet AS/NZS 2243.8 – not to be shared with a teaching laboratory.	3.4 6.9.3
Sufficient orderly storage for science equipment and materials.	3.5

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