Within the overall plan of a science department, how pupils learn in a particular laboratory depends on how the teacher manages the pupils, the design of the laboratory itself and equipment that is installed.

Pupil management and Design

When teachers set out to plan pupils' learning, they aim to create an appropriate atmosphere. This encompasses factors such as overall discipline, development of pupil self-discipline, relationships between teacher and pupil and relationships between pupil and pupil. Success comes when pupils respect their teacher, other adults (such as technicians and teaching assistants), each other, their surroundings, furniture and equipment. This success will mean that they actively want to learn. Achieving that success will lead to the teacher knowing and respecting their pupils as individuals and being professionally aware of what the pupils need to become enthusiastic learners in science.

The style of laboratory provision can do a great deal to support the good management of pupils but cannot take its place. Different types of pupil benching can support ranges of teaching and learning styles. Fixed octagons support teaching styles such as group discussion, as well as providing large areas of floor space for group activities and demonstrations. Movable rectangular benches allow for flexible arrangements and placement according to activity. Without good management, octagons can allow inappropriate pupil-pupil interaction, while movable benches can be moved (noisily) when that is not the teacher's intention. The traditional form of laboratory, with its long rows of benches, is not very appropriate to the teaching of today, due to its lack of flexibility; indeed this design is almost unchanged from the 19th century university chemical laboratories in Germany.

Design detail can sometimes ameliorate poor pupil behaviour but cannot do the job on its own. For example, gas taps with non-return valves prevent water being forced into gas pipes by enterprising young experimenters, but only good management will ensure that the taps are not turned on at inappropriate times. Installing robust pillar water taps, rather than swan-necked or swivelling taps, will help prevent damage to the taps themselves but only good management will stop water being sprayed all over the place!

Master controls for all services in the laboratory should be positioned so that the teacher can access them easily. Secondary cut-offs assist both maintenance and management of pupils by enabling one or more zones of a particular service to be isolated.

A stimulating environment

Good learning will result from a stimulating environment. Alternative teaching positions around the room, with different provision at each, helps keep pupils focussed and also stimulates teaching. Whiteboards need to stand out from the wall on which they are placed, which means no clutter on or around them and a colour scheme that makes the whiteboard more prominent. The overall colour scheme should be designed to keep visual interest but not be too dark overall; neutral shades all over rarely stimulate anyone.

Posters can provide a focus, but should not be too numerous or they lose their effect. Even health and safety equipment can add to the environment if kept to one obvious area, rather than scattered ad hoc around the room. In fact, considered provision of equipment will lead to a laboratory with a good atmosphere. However, good management is also needed to ensure that posters, science equipment and health and safety equipment are all used for the correct learning experiences. Removing any of these items to avoid pupils playing with them, damaging or stealing them, is an admission of less-than-good management and will impoverish the learning environment.

Floor area and class size

Floor area is an important issue, as is class size. Overcrowding puts severe pressure on class management and leads to both teacher and pupil stress if a factor for any length of time. No class in the 11-16 age range should be more than 30 in number; and 20 should be the maximum for a post-16 class. No style of benching can cope properly with a restricted floor area. Any laboratory under 90m^2 will restrict the number of fixed octagons that can be designed in, so restricting the number of pupil places available. Equally, movable benches become progressively less 'mobile' in floor area of less than 90m^2 and the number of possible arrangements is therefore reduced. Any form of overcrowding is bound to affect the risk assessments necessary for practical work, with the possibility of individual or group practical work being restricted or ceasing altogether, with the consequent drop in science achievement.

Direct teaching and demonstration

Direct teaching and demonstration both call for plenty of space for pupils to sit comfortably with good, direct sight-lines between them and the teacher, and any projection screens or boards. Many laboratories now have more than one teaching position with whiteboards, screens, and possibly a demonstration area in one of these positions. The pupils therefore have to be able to move to different positions in order to be able to hear and see well. Laboratories are nearly always bigger than ordinary classrooms and, for direct teaching, it can be very counterproductive to leave pupils seated at benches right at the back of the laboratory. The opportunity for pupils to move around occasionally should be seen as an advantage; some laboratory stools can feel very hard after a long period of inaction!

All styles of benching will support direct teaching provided the pupil-management is good. Movable benches can be rearranged to give seating spaces, with some benches being moved out of the way altogether. However, badly sited, fixed service-bollards can reduce this flexibility. Even when the positioning is well planned, careless installation may leave gaps too small to fit benches into designed patterns.

Fixed octagonal or teardrop benches can seat pupils facing many different directions, so what the benches lack in mobility is made up for in terms of alternative seating positions. Even overhead service provision to benches or bollards does not unduly affect sight-lines, if pupils are trained to shuffle in order to see round the down-sections.

Demonstrations can be the stuff of legendary science lessons. A demonstration bench can be a fixed bench, as one of the range of teaching positions, or can be an area into which a movable bench is slotted. In either case, all services must be available and there needs to be a reasonable length of bench to accommodate long equipment (such as trolley runways). Pupils should be fairly close to the demonstration, consistent with the risk assessment, so that they can see, hear and be part of the collective atmosphere. Trying to see a demonstration from the back of the class is impossible without aids and excludes pupils from the atmosphere generated by sitting together. Webcams or flexicams connected to video screens or digital projectors make small items large enough to see and their routine use hugely expands the range of possible demonstrations. However, their use should not be used as a way of keeping pupils glued to their normal class positions.

In cases of poor behaviour, it is certainly useful to be able to insist on pupils being seated and facing toward one point. The teacher, standing at this point, needs to have clear sight-lines to every pupil. However, to permit alternative teaching positions, this teacher point must obviously vary and flexibility in pupils' seated positions in the laboratory is necessary. In addition, an effective disciplinary procedure is for pupils to sit facing one point with the teacher standing at the other end of the laboratory or moving around, leaving pupils uncertain as to where lightning might strike next! Other measures involve isolating pupils by making them face away from the rest of the class.

Practical work

The main reason for providing laboratories is for pupils to carry out practical work. At the start of the lesson, bags and coats should be stored out of the way in some sort of rack, preferably to the side of the laboratory and near the door.

Textbooks and exercise books should be kept away from any wet areas. This can be managed fairly easily when service bollards are used with separate movable benches, but even octagonal designs will often have raised service centres upon which books can be placed (although these can then form a visual barrier if too high). Pupils stand up to carry out experiments, so benches should have space underneath and stools should be small enough to fit underneath the benches.

For health and safety reasons, pupils carrying out practical work must face towards their equipment. Therefore, working in groups implies facing inwards. This has implications for the training of pupils in terms of self-discipline. It also has implications for the teacher for, in order to check health and safety and to provide learning support for individuals and groups, s/he has to be constantly 'on the move' around the laboratory, using the proverbial 'eyes in the back of the head'.

For this supervision, layout and style of benches (both pupil benches and side benching) have to allow teachers to access all points in the laboratory fairly quickly in order to deal with incidents. There needs to be sufficient width between benches (and between walls, cupboards, etc) to accommodate pupils working and moving to collect equipment, and for teachers and support staff to pass comfortably through. Movable benches may appear to allow the best access but small floor areas, over-large classes, or even some arrangements of the benches can mean routes being obstructed. Octagonal

benching with linked units results in long routes, but not generally any longer than some arrangements of movable benches. What does cause problems with octagonal benches (or teardrops) is when links are also made to side benches, thus creating very long, chained islands. Placing some pupils on side benches to work allows more bench space per pupil, but safe gangways still need to be ensured, as do the sightlines for teacher supervision.

A good range of services needs to be available to pupils. Gas, mains electricity and water outlets are required in sufficient quantities to enable all pupils to work in small groups at the main pupil benches. Building Bulletin 80 suggests one gas tap and one electrical socket per pupil and one sink (with tap) per six pupils. A larger sink, with both hot and cold water, is required for hand-washing after certain experiments. Where computers are in use, more electrical sockets may be required and internet access is desirable.

In the case of chemistry, a fume cupboard will be needed, more than one being required for A/S and A2 lessons. Plenty of space should be left in front of fume cupboard positions for safe working. Demonstration fume cupboards need to be near the centre of a run of wall, rather than near corners, and they should be viewable from at least three sides.

If pupils with disabilities are included in the class, then adjustable benches, with services, will be required. This is especially the case for wheelchair users, for whom there should be more than the usual allowance of space around the bench. Most schools now have at least one laboratory thus equipped. However, if only one laboratory is so equipped, it should obviously be one with a fume cupboard in it and it may well mean changing laboratories to accommodate the appropriate classes. It would be far more flexible, efficient and accommodating for the pupil(s), if this were routine provision in all laboratories. For further advice on provision for pupils with special needs, see CLEAPSS Guide 77 'Science for Secondary-aged Pupils with Special Educational Needs'

Equipment and consumables have to be provided for practical lessons, procedures for which will be a matter for the whole department. Whatever decisions are made, the appropriate provision must be made in each laboratory. If equipment is brought in mainly from prep rooms, trolleys should be used and space designated within the laboratories (and the prep rooms) to park them. Side benches are often used for layout of equipment, so there should be sufficient lengths of side benching with areas dedicated to equipment layout, which are kept clear at all times, avoiding congestion

when pupils collect or deposit their equipment. General laboratory equipment such as lab stands, Bunsen burners, etc would normally be stored in the laboratory but, if other equipment is stored within the room, it will need to be accessible at the right time, not accessible when not needed (i.e. with cupboards locked) and much of it duplicated in each laboratory. There needs to be sufficient space in front of any cupboard to allow the doors to open and equipment to be removed safely.

Some experiments require lower light levels than normal. 'Dim out' is needed for many optical experiments in 11-16 science and can be provided by different types of blinds. However, some blinds are quite fragile. Control over light levels is a better solution than full blackout, which can cause safety problems when people cannot see to move around. Cased blackout blinds are sometimes recommended for laboratories specialising in physics. These are generally sturdier than other types, but are expensive. True blackout is best left to post-16 courses. Curtains are not appropriate for a laboratory due to the fire hazard from naked flames, such as those from Bunsen burners.

Zones for different activities

Differentiation by task can be the hallmark of well-managed learning. However, to enable different activities to go on at the same time within the laboratory means designing for different zones. Each zone needs to be easily set up and identifiable and will require services readily available. Large areas of bench may be needed for laying out posters. Adequate mains electricity and internet/intranet access will be needed for computers.

If projects or investigations need to be carried over for several lessons, a dedicated zone will be required. If the initial design of laboratories and prep rooms is planned with this in mind, then the appropriate space may be outside the actual laboratory but overseen through windows from laboratories and prep rooms. Support areas for SEN can also be designed to be outside the laboratory but still within the sight of teachers and technicians.

Role play

Space will be required inside the laboratory for activities such as role play and pupil-modelling of ideas like atomic structure. Movable benches can obviously live up to their name by creating free floor space, but poor positioning of fixed service bollards may restrict this. Moving benches can also create a great deal of noise. Peninsular benching – using a back wall bench and attached rows of benching – can create a large space at the front

of the laboratory suitable for role play or seating for demonstrations. Fixed benching of other shapes, octagons, teardrops and even circles, can provide large alternative spaces in corners of rooms and in front of teacher benches.

Group work

Group work for discussion and debate can take place at benches or with groups of stools in free areas. All styles of pupil benching allow group work although small tables are probably the most versatile. To arrange small groups (of 3 or 4) on octagonal benches, the groups sit along one side, with link benches proving useful here. Teardrops allow pupils to form small groups around the thin end and, in a more one-sided fashion, at the thicker end. Octagons, teardrops and circles are good for team competitions and debates, with one team at each bench.

Individual work

There is also a need for pupils to work individually, whether on research and study, writing tasks, calculations practice and even module tests. Some teachers may worry about benches that allow pupils to face each other, especially during tests. Bearing in mind that pupils can end up face-to-face regardless of the bench type if the class is not managed well, it may be necessary to seat pupils along side benches to optimise pupil learning. However, the design of the benches and cupboards must allow adequate knee spaces. Link benches for octagons, etc, can also suffer from lack of knee-space, leading to discomfort for any pupil seated at these.

ICT

ICT provision can be problematic. Technology in this area advances so fast that, by the time policy and design decisions are made, the equipment may well be out of date. Designs for new build or refurbished laboratories must therefore ensure that basic services are installed, and positioned correctly, so that both existing and future equipment can operate effectively. Cabling for internet access is relatively cheap if put in at the build stage. Wireless connection is already possible but, at present, there may still be major problems in an institution as large as a school, with many items of equipment competing for a part of the available bandwidth. If desktop computers are used, towers can be placed in cupboards under the benches and flat screens on the bench surface. It is still preferable to install wider side benches in order to allow all the associated equipment to be used along with the desktop (so enabling the older CRT screens to operate as well). Both desktops and laptops require an adequate number of mains electrical points.

Data-logging is a vital part of science experiments, investigations and demonstrations. This requires the data-loggers, computers to which to connect them (with appropriate leads and software), services (gas, electricity, water and drainage), and science equipment all in the same area. This is a tall order for any design and compromises will be necessary. One solution is for desktop computers to be installed on side benches, with data-loggers and their sensors already attached and all services provided to those side benches. Another is for dedicated trolleys with laptops and data-loggers, etc, to be brought in to the pupil benches, using the services already there. Despite dire predictions, at least one school has used laptops with science experiments for two years without any damage ensuing to the laptops. A common problem is that networked computers sometimes cannot work with the software needed for the data-loggers.

Projection

Data-projectors and interactive whiteboards are now more common. All new laboratory designs should have cabling pre-installed for these, and also for TV monitors, video players, DVD and good sound systems. Proper brackets for suspending such equipment from the ceilings or walls should be installed as part of the design; these also offer better security. The siting of brackets and of projection screens should be carefully thought through to ensure the best sight-lines for the pupils and to avoid glare off the screens.

A Supportive Environment

Some of the very basic design features of any laboratory relate to the comfort of both pupils and teachers. These should not be too comfortable, of course, but poor environmental conditions detract from effective teaching and learning.

Heating, ventilation and cooling systems should enable the laboratory to be warm enough in winter and cool enough in summer. Ventilation (and cooling) systems need particular attention. If ventilation is artificial, the system must not be so noisy as to affect the teaching or learning atmosphere. Ducting must not run from room to room as fumes and smoke from science experiments (even fire in emergency cases) may spread quickly from one laboratory to other rooms. Heating should be controllable within the room as Bunsen burners, for example, add a great deal of extra heat.

Ceilings can be lowered to create a better learning atmosphere and improve illumination. However, lowering ceilings too far can affect the volume of air in the room and thence the ventilation. Voids above false ceilings in one room

also have to be isolated from other rooms (using fire stops) so that, again, smoke, fumes and fire cannot spread out of control.

For new build, the orientation of the laboratory with respect to the sun's path and the placing of windows can do a great deal to prevent glare from the sun. This is especially important in the case of whiteboards and projection screens. It is vital to ensure that naked flames, such as those from Bunsen burners, are visible. Blinds are strongly recommended.

Illumination is an important design feature. Modern regulations demand higher levels of illumination than many schools have been used to and it is particularly important that benches receive good, diffuse lighting. As with solar glare, artificial illumination should not create glare on projection screens and whiteboards. Wiring the switches to allow groups of lights to be switched separately to the others will help a great deal; those lights near whiteboards and screens definitely need their own, separate switch. The use of energy-saving devices that switch lights off after a given length of time is inconvenient in any teaching situation and can be positively dangerous if the lights are extinguished in the middle of a pupil experiment or teacher demonstration.

The acoustics of a laboratory are vital to the 'feel' of the room. If the reverberation time is too long (the sound takes too long to die away), then the laboratory will be 'echoey'. In this situation, classes will always sound noisy, no matter how well behaved, and pupils will have difficulty hearing the teacher (especially those pupils with hearing difficulties). Conversely, too short a reverberation time will mean that a teacher's voice will not carry to the back of the laboratory. Reverberation time is increased by hard flat surfaces such as bare plaster, concrete floors and ceilings and flat bench tops. Soft display boards and vinyl flooring (especially with a proper underlay) absorb sound and therefore cut down on the echoes.

Stools should not be the last thing on the shopping list, as lack of finance at that stage may mean that only the cheapest types are purchased. Uncomfortable pupils then wriggle their way through lessons. Some of the cheapest models also have straight tubular steel legs which can carve their way through the floor if the ferrules come off or are worn away. Good stools do not cost much more and make a tremendous difference to the atmosphere of lessons. Not having to replace the floor every year also helps the finances! Factors to consider when choosing stools are foot rests, even back rests and the material and shape of the seat. However, back rests may

mean that stools will not tuck under benches for practical work and some stools are not stackable. Where the heights of pupils using the laboratory vary markedly, it may be useful to have some stools of different heights. Where laboratories are designed to have seating areas away from the benches, the use of ordinary chairs might be considered. For further advice on stools and chairs, see DfES Guide 7 'Furniture and Equipment in Schools; A Purchasing Guide'.

Floors should be non-slip for safety, especially when wet from accidental spills. Non-slip vinyl is very good but is abrasive. This means that the ferrules of stools wear out quickly and cleaners need appropriate cleaning pads for their machines. Smooth vinyl floor covering can look very nice and is more easily cleaned, but it becomes slippery when wet. If wood block floors are still in use, they must be kept sealed and only non-slip polish used on them.

Even the dimensions and installation heights of whiteboards are important. Teachers come in a variety of heights and so do pupils. All need to be able to write on the whiteboard. Conversely, if a whiteboard is placed too low it may become obscured by a teacher's desk placed in front of it.

Conclusion

Looking at all the design possibilities above, it is unlikely that any one laboratory could realise them all unless its floor area is over 100m^2. Compromise is almost inevitable. One possible solution is to create a range of laboratories that have different emphases (some with fume cupboards, others with project areas, etc). However this does reduce efficiency, because it is not possible to use all laboratories for all activities. The main aim should be to achieve the maximum flexibility and not to allow designs that constrain whole ranges of teaching and learning styles.

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'VIGNETTES' – ASE

1. Stools (and Floors)
2. Fume Cupboards
3. Eyewash
4. Teacher desks and demonstration areas
5. Water taps
6. Bags and Coats
7. Clutter and Colour

'CASE STUDIES' – ASE

1. New Build – good consultation
2. New build – minimal consultation
3. Conversion – science suite
4. Conversion – science room in a Special School
5. Conversion – science tutorial room
6. Refurbishment – on a restricted budget
7. Refurbishment – education authority programme
8. Refurbishment – good consultation
9. Refurbishment – of early 20th century laboratories

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