Acoustics in Schools
NEU guidance for members, reps and local officers

Teaching and learning are acoustically demanding activities. It is recognised, however, that a great number of classrooms in England and Wales have poor acoustics. This briefing examines a number of common acoustical problems in classrooms, and suggests some possible solutions.

It is widely acknowledged that good classroom acoustics enhance teaching and learning, improve student behaviour and reduce the risk of vocal strain for the teacher. But many schools were not built with due regard for the quality of classroom acoustics. The most common acoustical challenges facing classrooms, such as noise transfer between rooms and/or excessive reverberation in rooms, arise for a number of reasons, for example:

- the acoustical properties of 19th and early 20th century schools, which are often unsuited to modern teaching methods
- modern building methods, often reliant on lightweight materials which do not provide adequate sound insulation
- open-plan classroom designs, in which background noise and sound intrusion are difficult to minimise
- multi-purpose areas, such as halls, which must be acoustically suitable for a range of different activities
- specific subject areas in which noise can be a particular problem, such as music and design technology classrooms.

Poor acoustic conditions in the classroom increase teachers' vocal strain as most teachers find it difficult to make themselves heard above high noise levels. Recent surveys in the UK and elsewhere have shown that the incidence of voice strain/voice loss amongst teachers is amongst the highest across all occupations.

Prior to 2003, standards governing the acoustical properties of newly-built classrooms were little known and rarely enforced. Since 2003, however, Part E of the Building Regulations (as amended) has been applied to schools in the form of the first section of Building Bulletin 93. Despite this, even some new schools are failing to comply with minimum statutory requirements on acoustics. Glass, for example, is often favoured in modern school design, but it can cause problems as it is an excellent reflector of sound. Clearly, the best way of achieving good standards of classroom acoustics is for school building designs to follow the statutory requirements of Building Bulletin 93.

Furthermore, reference should be made to the useful section on acoustics in the guidance accompanying the School Premises (England) Regulations 2012, available at: legislation.gov.uk/uksi/2012/1943/contents/made

This states that:
"In a school with a good acoustic environment, people will experience:
- good sound quality – enabling people to hear clearly, understand and concentrate on whatever activity they are involved in

• minimal disturbance from unwanted noise (such as from activities in adjacent areas, teaching equipment, ventilation fans or road traffic).”

Furthermore it sets out a summary of Building Bulletin 93 (the title of which is Acoustic Design of Schools) as follows:
“‘Acoustic Design of Schools’ sets out performance standards in terms of:

a) adequate sound insulation of internal walls and floors to minimise disturbance from sound generated in adjacent areas
b) appropriate reverberation times (RT) to suit the teaching and other activities planned to take place in each space. Reverberation time measures how ‘echoey’ a particular room is. A relatively short RT is needed in most teaching spaces not only to ensure that speech, including teachers’ voices, is clearly heard and understood, but also to control the build-up of occupancy speech noise. Some spaces, for example some types of music room, require a longer RT.
c) suitable indoor ambient noise levels to enable clear communication. A part of the way to achieve this is to minimise disturbance from external noise by ensuring adequate sound insulation of the building. Suitable indoor ambient noise levels will vary depending on the activity taking place. Some noise sensitive activities, such as listening to music or learning a language, are less tolerant of background noise, as are rooms used for teaching pupils with hearing impairment and some other special educational needs.
d) adequate speech intelligibility in open plan areas to avoid disturbance from adjacent activities and to ensure that the wanted speech can be understood.
“Requirement E4 will be satisfied if performance standards (a) – (c) are met. School buildings are subjected to detailed design checks by building control bodies to ensure compliance with this requirement. Acoustic tests can be carried out on any new school accommodation to demonstrate that performance standards (a) – (c) are achieved.”

Meanwhile, regulation 7 of the School Premises Regulations 2012 states that: “The acoustic conditions and sound insulation of each room or other space must be suitable, having regard to the nature of the activities which normally take place therein.”

The guidance to the School Premises Regulations 2012 states that classroom conditions should be such that teachers are able to communicate without straining their voices. It also makes it clear that certain types of spaces, such as music rooms, recording studios, open-plan areas and rooms where pupils with hearing impairment are taught might require higher acoustical standards than those applying in normal classroom areas.

Pupils with special needs may need to be taught in spaces with lower noise levels and shorter reverberation times than in mainstream classrooms, the guidance points out. “Special schools and SEN units in mainstream schools must therefore be designed to a higher acoustical standard. Where pupils with these special needs are taught in mainstream schools, the acoustics of the spaces where they are taught may need to be enhanced to the same standards as those in special units. Provision will usually be required to teach these pupils in smaller groups so that ambient noise from other pupils is lower and the distance between teacher and pupil is minimised.”

Finally, the School Premises Regulations 2012 guidance points out that good management of acoustic conditions in schools is essential. Arrangements to maintain good classroom acoustics must not be allowed to deteriorate through neglect.

Decibels

The most common measure of a sound's level is the decibel, abbreviated dB. On the decibel scale, the smallest audible sound (near total silence) is 0 dB. A sound ten times more powerful than near total silence is 10 dB. A sound 100 times more powerful than near total silence is 20 dB. A sound 1,000 times more powerful than near total silence is 30 dB. In other words, doubling the intensity of a sound does not result in a doubling of the decibel level, as the dB scale is logarithmic not linear.

Here are some common sounds and their decibel ratings.

Source	dB
Faintest audible sound	0
Whisper	20
Quiet home environment	30
Soft hi-fi	40
Speech	50-70
Café	80
Pneumatic drill	90
Accelerating motorcycle	100
Rock concert	120
Jet engine	140

Signal-to-noise ratio

Signal-to-noise ratio is a simple comparison that is useful for estimating how understandable speech is in a room. The sound level of the teacher's voice in dB, minus the background noise level in the room in dB, equals the signal-to-noise ratio (S/N) in decibels. The larger the S/N, the greater the speech intelligibility. If the S/N is negative (ie the background noise is louder than the teacher's voice), the teacher will be hard to understand. Note also that the S/N varies throughout the room as the signal and noise levels vary.

Typically, the S/N is lowest either:

• at the back of the classroom, where the level of the teacher's voice has fallen to its minimum value, or

• near a noise source, where the noise level is at its maximum, such as near a heater or an air conditioning unit.

Studies have shown that, in classrooms with a signal-to-noise ratio of less than +10 dB, speech intelligibility is significantly degraded for children with average hearing. Ideally, for good speech intelligibility, the level of the voice needs to be at least 10 to 15dB above the background noise level.

For children with some form of hearing impairment, audiologists recommend a difference of 20-30dB between voice and background noise.

Reverberation and sound absorption

Ideally, classrooms should have reverberation times (RTs) in the range of 0.4-0.8 seconds, but reverberation times in many classrooms fall outside these limits. There are two ways to reduce the reverberation time of a room: either the sound absorption must be increased or the volume must be decreased. Increasing the sound absorption in a classroom is generally easier to achieve than reductions in volume.

Sound absorption can be improved by the addition of more ‘soft’ materials, such as fabric-faced glass fibre wall panels, carpet, or acoustical ceiling tiles. For many older classrooms with high ceilings, the addition of a suspended ceiling of sound-absorbing tile can significantly improve the acoustics by simultaneously decreasing the volume and increasing absorption.

Having too high a level of sound absorption, however, can create an acoustically 'dead' space resulting in difficulties in communicating. A suspended ceiling with a noise reduction coefficient (NRC) in the order of 0.60 generally provides most classrooms with the required reverberation time 1.

The Building Regulations, through Building Bulletin 93, recommend a maximum reverberation for most classrooms of either 0.6 secs or 0.8 secs, depending upon whether in a primary or secondary school. Long reverberation times favour the build-up of background noise and can impair intelligibility, but short reverberation times can limit the strong reflections needed for those at the back of the classroom to hear clearly.

Flutter echo
When two flat, hard surfaces are parallel, a sound can rapidly bounce back and forth between them and create a ringing effect known as a flutter echo. This can happen between two walls, or a floor and ceiling.

To eliminate flutter echo between two hard, parallel walls, one or both of them can be covered with fabric-faced glass fibre panels or a similar sound-absorbing material. This works well if the panels are staggered along the opposite walls so that a panel on one wall faces an untreated surface on the opposite wall. Splaying two walls at least eight degrees out of parallel will also eliminate flutter echo between them.

For a diagram showing how some of these measures can be applied to an existing classroom space, see Appendix 2.

Noise from Adjacent Rooms
Noise from adjacent rooms disrupts the learning process, especially during quiet reading times or test-taking. In recent decades, the need to lower construction costs has led to the use of thin, lightweight wall materials that provide little noise reduction. In the 1960s and 1970s, many open-plan classrooms were built with no partitions whatsoever between classrooms. In some schools, such spaces have since been partitioned, but noise reduction between rooms may still be insufficient.

Where the adequacy of a wall dividing two classrooms is in doubt, the following simple test can be applied: set up a television or video monitor in one room and set the sound level so it can be comfortably heard at the back of the classroom. Then go into the neighbouring classroom and listen for sounds from the equipment next door. If sounds

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are faint or inaudible, the barrier is sufficient. If sounds are fairly loud, and especially if words are intelligible, the partition between the rooms needs to be improved.

The noise reduction of exterior walls is also important since many noisy and potentially disruptive activities go on outside the school. Most schools are built with brick or concrete block exterior walls - which are good sound barriers - but with inadequate windows that permit considerable sound transmission. To provide noise reduction, windows must be well sealed. Double glazing provides better noise reduction than single-paned glass (as well as providing better thermal insulation and decreased energy costs).

Music Teachers

Music teachers are at particular risk of sustaining hearing damage as a result of prolonged exposure to very high sound levels in their daily work. Recently, the Health and Safety Executive (HSE) has begun to look more closely at this risk and now suggests that music teachers may need to consider some form of hearing protection in the classroom. The HSE has collaborated with practitioners in the music and entertainment industries to produce detailed guidance on managing the risk of excessive noise to music teachers. This is available at:
soundadvice.info/schoolsandcolleges/schoolsandcolleges-step1.htm

Among other things, the guidance makes the point that many musical instruments create sound that is louder than current noise regulations allow. A cornet, for example, can reach 140 decibels - equivalent to a jet plane taking off. Exposure to such levels of sound can cause immediate and lasting damage to hearing, while lower levels can cause problems to build up cumulatively.

The Control of Noise at Work Regulations 2005

The Control of Noise at Work Regulations 2005 specify a daily or weekly exposure action value (EAV) of 80 decibels. At this level, a risk assessment must be undertaken, and suitable control measures put in place. These might include the wearing of earplugs, standing behind a noise screen and/or advising those at risk not to stand directly in the line of a musical instrument, for example. The regulations also stipulate an upper EAV value of 85 dB, and an absolute limit, the exposure limit value (ELV) of 87 dB. Should this level be exceeded, the employer would be in breach of the regulations.

Controlling excessive noise

Employers must carry out a risk assessment if noise levels are likely to reach or exceed the lower EAV (80dB) and take appropriate action to control such levels. Where sound levels are likely to reach the upper EAV (85dB) the employer must take co-ordinated action through a ‘programme of organisational and technical measures’ in order to reduce noise levels in a systematic and thorough manner.

When looking at ways of controlling workplace noise levels, employers might consider:
• changing working methods
• changing work equipment
• alterations to design of work layout and work stations
• provision of suitable and sufficient information and training for employees

• limiting duration and intensity of exposure to noise.

Employers must not expose workers to levels of noise above the ELV (87dB). If the ELV is exceeded, employers must reduce exposure to below that level and prevent it happening again. Noise levels of 87dB have regularly been recorded in classrooms, and these high noise levels can present significant risks to teachers' hearing. Prolonged exposures to noise over a number of years can cause hearing loss. Noise can also cause hearing problems such as tinnitus, which is experienced as ringing in the ears, and can be very distressing.

Environmental noise

The external environment where teachers work can also have an impact on classroom acoustics and hearing. For instance, the HSE states that working in an environment with intrusive noise, such as a busy street, for most of the working day is likely to indicate a noise problem.

Many schools, particularly in urban areas, are situated near busy towns, roads, railway lines, airports etc. Therefore, the noise of these environments has the potential to reach or exceed the exposure levels. Employers are required to implement measures such as engineering controls, when noise reaches 85dB. Noise from road traffic can be alleviated by noise barriers, as well as landscaped mounds of earth.

In one incident, a retired NEU member suffering substantial hearing loss was told that this condition was compatible with someone whose working life was in a very noisy environment. The member's doctor was of the opinion that working in a school besides a busy motorway for many years was likely to have caused their extreme hearing loss. Instances such as this highlight the need for employers to ensure sufficient controls are in place to minimise noise.

Voice amplification systems

A typical such system consists of a wireless microphone worn by the teacher and one or more loudspeakers located at the front of the room, in the ceiling or along the walls to distribute the sound to the students. Amplifying the teacher's voice raises the signal-to-noise ratio, which improves speech intelligibility and reduces vocal strain. This can be useful in a room with a moderate amount of mechanical noise that would otherwise be difficult or expensive to silence. Voice experts agree that such systems can be particularly helpful – among other things - in preventing trauma to the vocal fold mucosa by reducing the need to speak loudly and forcefully.

However, such systems also have their limitations. An overly-reverberant classroom, for example, will cause the sound from the loudspeakers to build up and remain unintelligible. Whether or not a sound reinforcement system is used in the classroom, it is vital to employ acoustical treatments that reduce reverberation time.

Another drawback to sound reinforcement systems is that they amplify only the teacher. Students are not amplified when they ask the teacher questions or talk among themselves while working in groups. Some systems provide an extra handheld microphone that students can pass around. However, this is a cumbersome solution that interferes with spontaneous discussions. Also, if the microphone is not kept close to the person speaking, it will pick up as much ambient noise as speech, and the signal-to-noise ratio will not be improved. Still another problem is that the amplified sound will become noise for adjacent classrooms.

Finally, it should be borne in mind that such equipment is not a panacea for vocal problems and should not be used by those who have sustained voice damage without taking advice from an appropriate health professional (such as a speech therapist). Despite these shortcomings, sound reinforcement systems can be cost-effective improvements for classrooms with high noise levels, and are usually better than no modifications at all. For this reason, many teachers have found personal amplification systems can be both necessary and effective tools of the trade. The equipment is capable of significantly reducing the chances of vocal damage, both for those with healthy voices and those who have recovered from a previous voice problem, and wish to avoid a relapse.

Voice amplification will function at its best where:
- the equipment is suitable for the room
- it is installed by a qualified person e.g. a sound engineer
- the teacher receives appropriate training in its correct operation.

For example, unless you have ‘fold-back’ monitor speakers facing towards you, you may not be able to hear your own voice very well, or perhaps not at all. This can lead to a tendency, albeit an unwitting one, to speak more loudly than you might mean to – thus forfeiting the benefits of using vocal amplification in the first place.

Checklist for NEU safety representatives

1. Include teacher experience of classroom acoustics as part of health and safety inspections.

2. Evaluate which staff might be at particular risk of poor classroom acoustics.

3. Ensure the school has completed a full risk assessment of classroom acoustics.

4. Ensure that control measures are implemented in full.

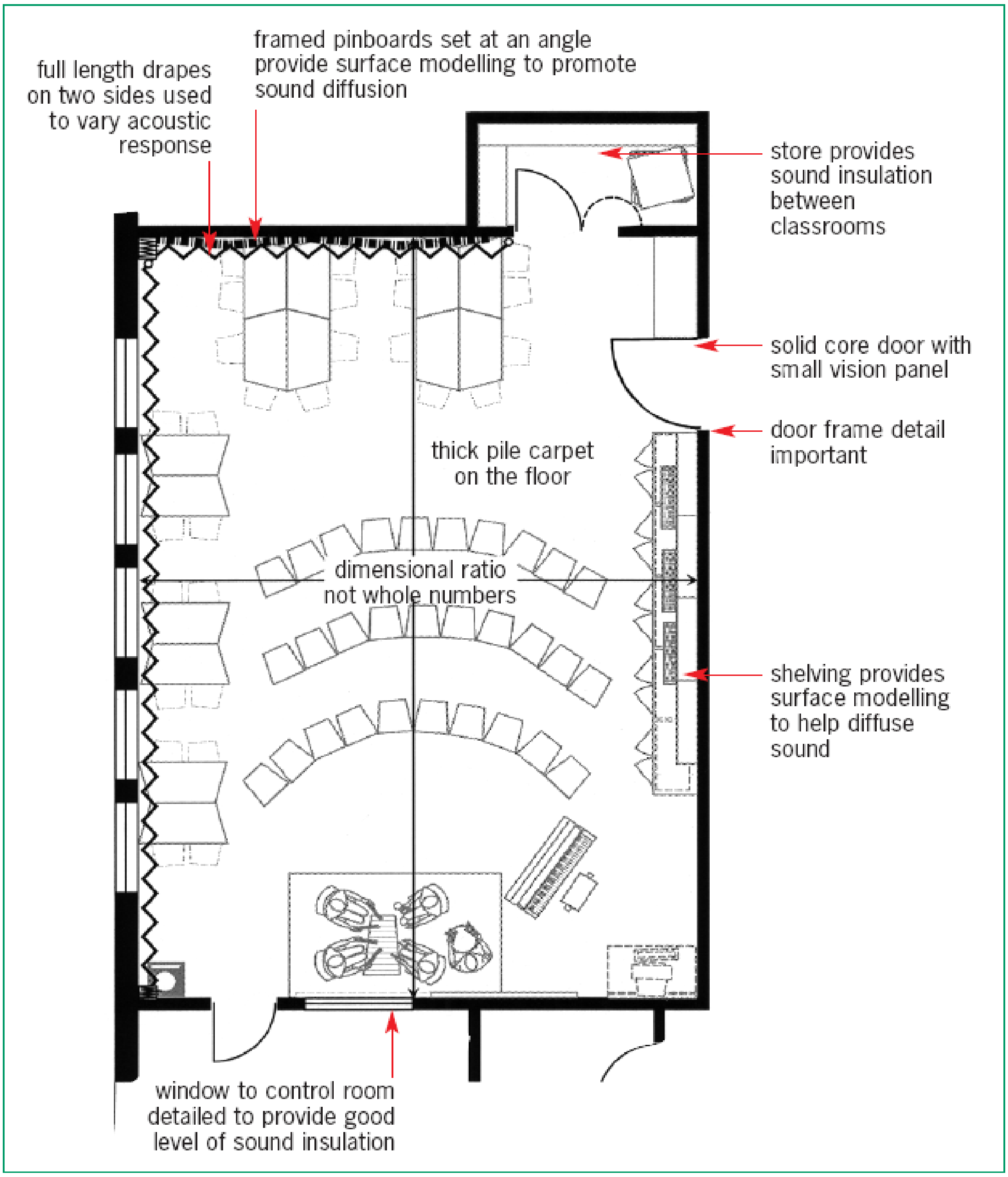
5. Ask to participate in any discussions about planned refurbishments at school.

Appendix 1
Noise reduction coefficient (NRC) values for common building materials

Material	NRC
Brick, painted	0.0-0.02
Brick, unpainted	0.0-0.05
Carpet, heavy, on concrete	0.2-0.3
Carpet, heavy, on foam rubber	0.3-0.55
Concrete, smooth	0.00-0.2
Drapery, medium weight	0.55
Glass	0.05-0.1
Seating (occupied)	0.8-0.85
Seating, unoccupied, metal	0.3

Appendix 2

Suggested acoustic treatments to music classroom (from Building Bulletin 93)



Suggested modifications to a small music practice room (from Building Bulletin 93)