



Designing Quality Learning Spaces

ACOUSTICS

Version 2.0, September 2016



Document history

The table below is a record of the changes that have been made to this document:

Revision date	Version	Summary of changes
2007	1.0	First version for general release
September 2016	2.0	<ul style="list-style-type: none">• Substantial changes to content to reflect current teaching practise and flexible learning spaces.• Document rewritten for a target audience of architects, designers and engineers involved in the design and specification of schools.• Document restructured to bring mandatory requirements to the first section of the document.• Ministry requirements are now clearly marked as 'mandatory' or 'recommendation' to make them easy to find throughout the document.



Foreword

The Designing Quality Learning Spaces (DQLS) series of documents was first released by the Ministry of Education in partnership with the Building Research Association of New Zealand (BRANZ) in 2007. This is the second version of the DQLS - Acoustics, and there have been substantial changes made in this update.

The DQLS Acoustics version 2.0 is mandatory for all projects starting after 1 January 2017.

Background

The Ministry owns one of the largest property portfolios in New Zealand, with more than 30,000 buildings in about 2,100 schools. Learning space design and upgrade is commissioned through various mechanisms – nationally via Ministry programmes, regionally by the Ministry’s delivery managers, and locally by Boards of Trustees.

The way teachers and learners engage with each other have changed significantly in the last decade. School design needs to reflect the changing needs of the users, and learning spaces must be designed to support the way they are being used. The update of the DQLS series has been undertaken to ensure the spaces that are built are flexible and can support the many different styles of teaching and learning.

Acoustics

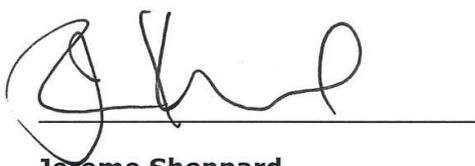
The acoustic performance of learning areas has a direct impact on the usability of the space and the learning outcomes. As educational spaces increasingly become more open to support diverse activities, they also need to be designed and built to have high acoustic performance. Many of the technical issues and lessons addressed in this document have emerged from the reviews of school designs undertaken by the Ministry’s Design Review Panel.

Acknowledgement

The Ministry gratefully acknowledges the assistance of BRANZ, the Acoustic Society of New Zealand and Victoria University of Wellington in creating this document.

Feedback and updates

We are seeking to constantly improve the content and usability of our documentation. If anything in this document requires clarification please contact the Ministry through Property.Help@education.govt.nz. Your feedback will help us to ensure this document is maintained as a valuable resource for all of those involved in the design of our schools as effective learning environments.



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Introduction

Purpose

This document provides technical requirements and guidance for the acoustics design of school buildings in New Zealand. It provides guidance for design teams to plan and specify fit for purpose schools, which include the provision of flexible learning spaces (FLS) that support the creation of innovative learning environments (ILE) for schools to deliver the New Zealand Curriculum and Te Marautanga o Aotearoa.

Intended audience

The Designing Quality Learning Space (DQLS) series of documents are written for designers and engineers involved in the design and specification of New Zealand schools. They also provide relevant technical guidance for property managers undertaking school projects.

The DQLS documents are also to be referred to by property professionals for the purpose of:

- briefing design teams,
- informing and reviewing designs and specifications,
- estimating costs,
- undertaking Technical Post Occupancy Evaluations.

Appendix A contains general overview information about acoustics that may be of interest to Boards of Trustees and property professionals who are new to working on education property projects.

The DQLS documents set the performance requirements for new schools and the benchmark for upgrading existing schools. The values given are intended to maximise the utility and flexibility of learning spaces for all users. The documents aim to promote inclusive design and take into account the general range of abilities and special education needs expected to be found in New Zealand Primary Schools and Secondary Schools. However learners with specific special learning needs may require provisions in addition to the requirements set in the DQLS document series.

Document hierarchy

The Ministry is committed to providing quality learning spaces to enable education and learning in schools to achieve the objectives of the Education Act 1989.

The Designing Schools in New Zealand (DSNZ) document is the overarching guidance for school design. It states the Ministry’s policies for schools, the project design process and general principles to be applied during planning and design. The DQLS documents support the DSNZ by providing detailed performance requirements for refurbishing and creating new school buildings.



Acoustics and learning

Good acoustic design supports students in their learning activities.

Incorporating good acoustics is essential to support learning for all learning spaces, from traditional classrooms to flexible learning spaces. It is needed to support the broader range of learning activities that are involved in innovative teaching and learning practise.

When excessive background noise and reverberation are not addressed it can make it hard to hear and understand speech. This is especially important for younger students who haven't yet developed the skills that allow them to process conversations in the presence of background noise. Excessive noise may lead to students missing key words, phrases and concepts.

Good acoustic design will support students with hearing impairment and those with learning difficulties. These students can have difficulties with listening and concentrating in learning spaces with poor acoustic performance. Learning in spaces with poor acoustics can be especially hard for students where English is not their first language.

Many schools are choosing to create flexible learning spaces. They can provide significant benefits by connecting a larger number of students in parallel activities that support the diverse learning needs of students. However, just as in traditional classrooms, for these flexible spaces to support learning it is important that they are acoustically engineered to address potential background noise issues.

Good acoustic design includes designing to manage noise generated from outside, for example roads close by, as well as noise generated within the learning space including mechanical noise such as fans.



Figure 0-1 Flexible learning space with break out spaces that allow co-teaching of learning groups, with teacher / student and student / student learning opportunities.



Importance of good acoustics

Research in New Zealand and overseas confirms that good acoustics contribute to good learning spaces. Poor acoustics can impact on a student's ability to learn and a teacher's ability to teach. The Oticon Foundation's study in New Zealand traditional primary school classrooms noted that:

- 71% of teachers felt that internal classroom noise was a problem,
- more than 33% of teachers indicated they had to speak at a level that strained their voices,
- around 50% of teachers said they had to considerably raise their voices during group work.

With more and more schools moving towards [innovative learning environments](#), it is important these lessons from the past are used to effectively design our future learning spaces.

Along with developing focus and self-direction, the ability to listen is central to a student's learning success. Listening is critical to the process of developing language skills and to the learning process. While there may be factors relating to the student that impact their listening ability, the following acoustic factors can be managed through good design:

- ambient noise (both outside and inside the room),
- activity noise from other learning activities in nearby spaces,
- reverberation,
- low signal-to-noise ratio (the ratio of the teacher's voice to the ambient noise).



Figure 0-2 Multiple groups of students working effectively and independently in an acoustic environment that allows them to focus and be sufficiently free from distraction.

The overall design, and more specifically spatial management, has a significant influence on successful acoustic performance. For example, smaller break-out spaces can provide for individual and small-group learning activities, while larger break-out spaces enable didactic teaching and presentations to take place with some degree of acoustic separation. With careful acoustic design didactic teaching can also be carried out side-by-side in flexible learning spaces.

Adapting to different teaching methods

Many teaching spaces in older schools do not perform well acoustically even for the types of learning activities and teaching practices that have been traditionally used. Both the layout and acoustic performance are not optimal for collaborative teaching practice, or supporting the variety of learning settings, ranging from individual student learning and small groups to collaborative work and large group workshops or discussions.

Catering for diverse learning styles, personalised learning programmes and integrated curriculum learning teachers are more often collaborating together and act as an activator for self-learning. They move around the learning spaces, working with individuals or groups, where the size of the groups can range from pairs to several class groups at a time.

The evolving focus on self-directed learning reduces the traditional emphasis on acoustic connections between the teacher's voice and the whole-class group. It establishes the need for acoustic privacy for students engaged in self-directed learning or in small group tasks, and acoustic management of larger spaces to reduce background noise, particularly during collaborative learning sessions.

Acoustic management of larger spaces to reduce background noise is just as important as it is for the traditional cellular classroom.



Figure 0-3 Teachers are often an activator for self-directed learning; the acoustic environment needs to support self directed learning for all students.



DQLS Acoustics - overview

The DQLS - Acoustics guidance has been developed to set the minimum standard for school buildings. Getting the acoustics right is fundamental to enabling students and teachers to communicate and understand each other. Good acoustics and flexibility in our learning spaces will support a range of innovative teaching and learning approaches to meet the needs of students.

Ministry requirements and key information are in RED, look for the  symbol.

Ministry recommendations and other key concepts are in BLUE, look for the  symbol.

To achieve good acoustics and maintain flexibility of the space, designers are to:

- look for every available opportunity to use highly absorptive materials on floors, ceilings, and walls,
- typically provide for 3-4m² per learner to allow better acoustic separation,
- provide a range of adaptable learning spaces, including spaces that can be acoustically separated when required (such as break out spaces).

Just as important to consider is the way users manage their activities within learning spaces. More open plan layouts provide flexibility, but they require educators to coordinate activities to maximise the teaching benefits. By doing so, they can also minimise disruptions and manage the risk of hearing and speaking difficulties for other users of the space.

The DQLS - Acoustics guidance has been prepared on the basis that teaching staff will coordinate learning activities within the learning spaces to manage noise extremes.

Integrated design philosophy

Designers are to apply an integrated design approach to the design of schools and learning spaces. The flexibility of a space, acoustics, ventilation, daylight and energy use are interrelated and a change to one factor often impacts other factors. For example, an effective but noisy ventilation system will introduce fresh air but also increase ambient noise levels.

Optimising learning spaces

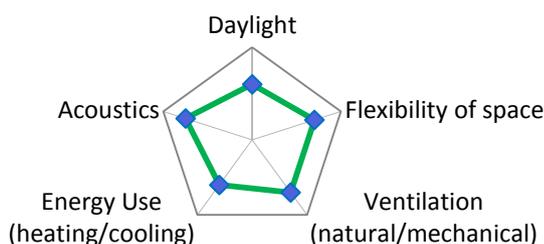


Figure 0-4 An integrated design approach is required to ensure quality learning spaces are optimised over all 5 environmental parameters.

While all environmental factors need to be optimised, the following hierarchy is essential when making value engineering decisions to reduce cost:

Flexibility of space > **Acoustics** > Ventilation > Daylight > Energy Use

The importance of communication in learning spaces is a foundation requirement for teaching and learning.



1. Minimum acoustic performance and general design principles

This section states the minimum performance requirements for acoustics in schools. The performance requirements are set at a level that will provide good speech intelligibility.

The management of acoustic parameters affect speech intelligibility within a space. Speech intelligibility is necessary for clear communication. Designers should select acoustic systems carefully with speech intelligibility as a top priority.

Designers will need to balance the acoustic performance and account for the additional design considerations specific to school learning environments. The four key acoustic parameters are:

- [Reverberation time](#)
- [Sound insulation between learning spaces](#)
- [Impact sound insulation](#)
- [Ambient noise level](#)



Figure 1-1 Flexible learning spaces enabling collaborative teaching practices require good acoustic design. This classroom uses highly acoustic absorptive ceilings, acoustic absorptive wall surfaces, acoustic absorptive flooring, and wing walls and exposed rafters to break up sound paths.



1.1 Reverberation time

The reverberation time (RT) affects the ease with which people can hear and understand each other – the speech intelligibility. Spaces with short RTs will often feel ‘dead’ or ‘quiet’, and spaces with longer RTs will sound ‘live’ and ‘dynamic’. Shorter RTs are generally better for speech intelligibility. The optimal RT for a space will depend on the intended use and acoustic profile required.

The RT is affected by the volume of the space and the type of acoustic absorption on the bounding surfaces within the space (refer [Section 1.5.1](#)). Designers will generally use acoustically absorptive materials to reduce the RT (refer [Section 5.3](#) for examples).

[Table 1-1](#) states best practice RT for various spaces. The ranges reflect that each learning space type may have a different volume and acoustic profile. **The measured RT is to be the mid frequency average (RT_{MF}) for the learning space.**



Table 1-1 Design reverberation times in different learning spaces

Learning space	Reverberation time (s) mid frequency average (RT _{MF})
Breakout spaces / meeting spaces / teacher work spaces	0.4 – 0.5
Flexible learning spaces	0.5 - 0.8 Refer Figure 1-2
Cellular classrooms	0.4 – 0.5
Music learning spaces	0.6 - 0.8 Refer Section 4
Halls / Multipurpose spaces	0.6 - 0.8 Refer Figure 1-2
Gymnasiums	0.8 - 1.5 Refer Section 4
Technology and science spaces	0.6 - 0.8 Refer Section 4
Libraries	0.5 – 0.8 Refer Section 4



For large volume spaces, designers can use [Figure 1-2](#) as a guide to determine a suitable RT. The RT can increase proportionally to the volume of the space and achieve similar acoustic performance.

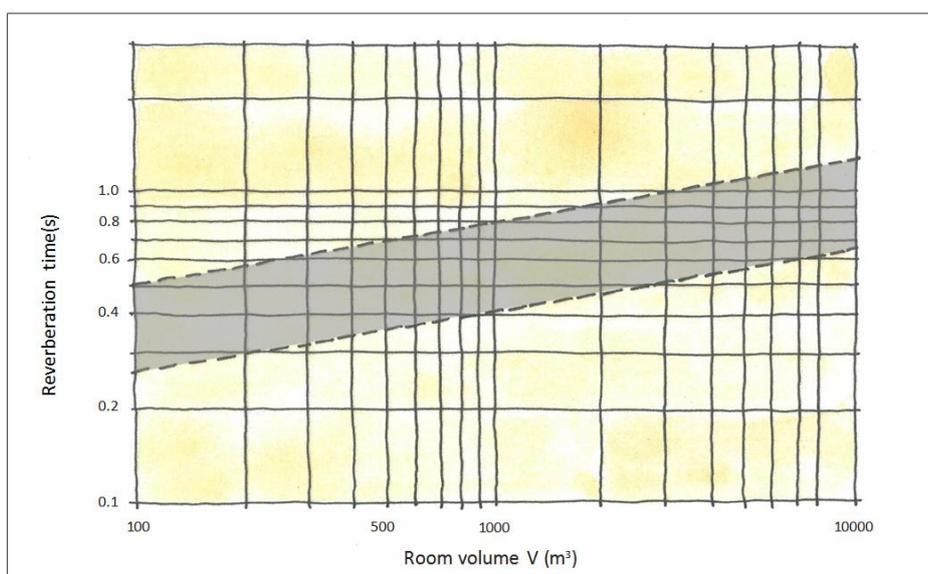


Figure 1-2 Optimal reverberation time ranges for larger volume learning spaces.

Large shared teaching spaces are complex spaces that require careful design. **If there is doubt over the appropriate RT, designers are to consider consulting an acoustic specialist.**



1.2 Sound insulation

Sound insulation reduces sound transfer between spaces. It is rated using sound transmission class (STC) values. The values in [Table 1-2](#) and [Table 1-3](#) are best practice performance levels for schools. These are the minimum requirements for ensuring sound transmitted between learning spaces causes minimal noise transfer for most anticipated activities.

Some spaces are used frequently for activities that produce high levels of noise or require high levels of acoustic privacy. Designers are to establish suitable STC values for the wall, floor and ceiling systems in those specialist spaces to ensure they can meet the other Ministry requirements.

1.2.1 Sound insulation requirements between activity spaces within schools

Required STC values between separate learning spaces partitioned from each other and are managed separately. Note where impact sound sources are also likely to be produced this will have to be designed for in conjunction with the STC requirement.

Table 1-2 Design sound insulation performance (STC rating) for adjoining learning spaces

Learning Space Types	Adjacent learning space						
	Flexible learning spaces	Meeting, library, cellular classroom	Technology learning space ³ (moderate noise)	Technology learning space ³ (high noise)	Gymnasium	Halls / Multi-purpose spaces	Music learning space ⁴
Flexible learning space	25-50 Refer Table 1-3	50²	55	60¹	60¹	60¹	60¹
Meeting, library, cellular classroom		50²	55	60¹	60¹	60¹	60
Technology learning space ³ (moderate noise)			50	50	55	55	60¹
Technology learning space ⁴ (high noise)				55	55	60¹	60¹
Gymnasium					55	60¹	60¹
Halls / Multi-purpose spaces						60¹	60¹
Music learning space ⁴							60



¹From an acoustic design perspective these spaces are not to be located directly adjacent to each other. Consider the benefits of these spaces being adjacent versus the acoustic management.

² Where schools require connectivity between adjacent spaces and there is a degree of coordination and management of the learning activities in both spaces a lower value may be acceptable.

³ Not all learning activities associated with technology and music produce excessive noise, so where activities can be identified and separated from each other, the spaces for learning activities which produce noise similar to general learning can use the separation levels for flexible learning spaces.

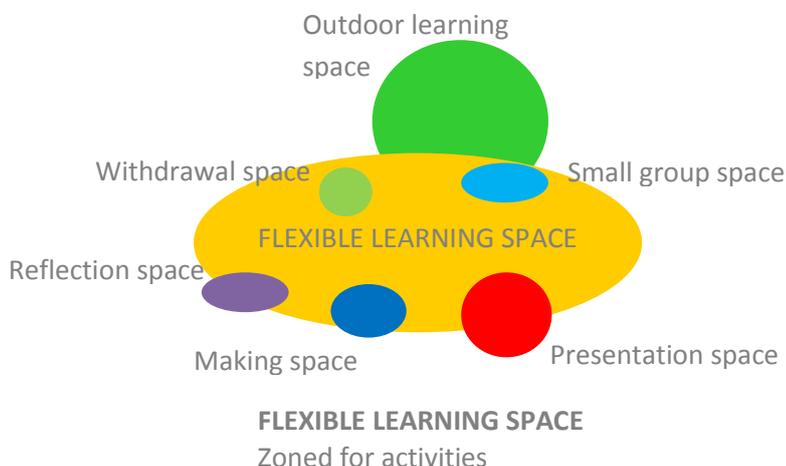


Sliding doors should have a minimum performance of STC 25. Note they are considered unsuitable for separating specialist spaces where loud sounds are made, for example music spaces and technology spaces where machinery and tools are used.

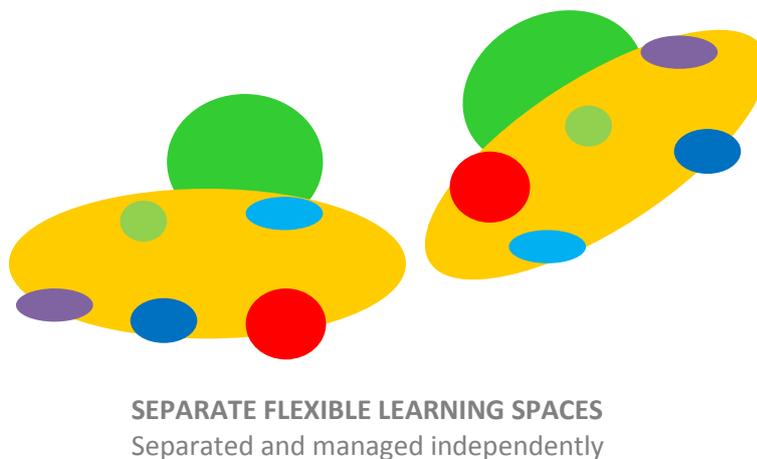


1.2.2 Sound insulation requirements within flexible learning spaces

Flexible learning spaces work best when educators collaborate and coordinate learning activities within the space. This can be by effective scheduling of learning activities to avoid clashes between quiet and noisy activities. This co-teaching practise is considered a ‘coordinated’ flexible learning space.



Some schools are configured with flexible learning spaces adjacent to each other. These create learning hubs, which may be managed in a coordinated manner or managed independently from each other.



When adjacent flexible learning spaces are managed independently these are considered ‘separate’ flexible learning spaces.



The figures in [Table 1-3](#) are the minimum performance requirements for sound insulation within FLS areas (coordinated) and between two or more adjacent FLS (separate).

Table 1-3 Design sound insulation performance (STC ratings) for adjacent learning spaces

Adjacent Spaces	Flexible learning spaces (coordinated)	Flexible learning spaces (separate)	Break-out learning spaces and teacher work space	Quiet breakout and withdrawal spaces (for assessment or specialist activities)
Flexible learning spaces (coordinated)	Adequate sound insulation and absorptive materials to achieve other acoustic requirements within the FLS space	Refer note 2	STC 45 wall 35 fixed glazing 25 glazed door ¹	50 wall 38 fixed glazing 25 glazed door ¹
Flexible learning spaces (separate)		50 wall ² 38 fixed glazing	50 wall 38 fixed glazing 25 glazed door ¹	55 wall 38 fixed glazing 25 glazed door ¹
Break-out learning spaces and teacher work space			50 wall	50 wall
Quiet breakout and withdrawal rooms for (assessment or specialist activities)				50 wall

¹ Sound sensitive areas should be located away from doors because doors reduce the effectiveness of sound insulation. The size of door openings should also be considered. Some students, particularly in primary schools, may not be able to operate doors with sound seals so designers need to develop innovative designs which do not require high levels of sound separation.

² Where separate learning hubs are connected via openings, void spaces, open stairwells, or are part of a larger space, the sound-ratings tabled above do not apply. In these cases, sound separation should be achieved through a combination of distance, screening and sound absorption. Some coordination between learning hubs may be required.



1.3 Impact sound

Managing sound impact is particularly important from upper floor spaces. The performance of various materials is rated by using the Impact Insulation Class (IIC). For all learning spaces, designers are to achieve a **minimum impact insulation performance of IIC 55** between floors. For external decks see [Section 2.3.3](#). **Isolation of noisy machinery will require specific acoustic engineering to achieve this performance.**



A reduced standard of IIC 50 is acceptable for areas that are < 10% of the floor area of the space below it.

1.3.1 Rain noise

FLS are typically large open spaces with large roof areas. Control of rain noise needs to be considered. Construction solutions to minimise rain noise depends on the local climate of the school, the frequency of rainfall, and the level of disruption it creates. Acoustic performance for rain noise is calculated using Noise Criterion (NC); note a lower number is better.

Designers are required to achieve a roof and ceiling sound performance of NC 45 or less.



Some typical construction examples and performance are given in [Section 5.4.1](#) for a rainfall of 20mm/hr.

Higher rainfall rates or localised climate conditions may require guidance from an acoustic consultant.



1.4 Ambient noise

Ambient noise levels are based on unoccupied spaces with closed windows and mechanical ventilation systems in their normal operating mode. Designers are required to achieve designs with ambient noise levels given in [Table 1-4](#). The range of values reflects the different arrangements possible within each learning space.

Table 1-4 Design ambient noise levels in different learning spaces

Learning space	Ambient noise (dB L _{Aeq})
Breakout spaces / meeting spaces	35–40
Flexible learning spaces	35–45
Cellular classrooms	35–45
Music spaces	25-35 Refer Section 4
Halls / Multipurpose spaces	30-40 Refer Section 4
Technology spaces	40–45 Refer Section 4
Libraries	40-45 Refer Section 4
Teacher work spaces (if teachers require a quiet space while learning is occurring in adjacent spaces)	35–40



1.5 Key design considerations

1.5.1 Acoustic absorption

Acoustic absorption within learning spaces is provided primarily by soft fibrous materials. The effectiveness of the material is determined by a variety of factors including, density, fibre size and thickness. High performance products include high-density fibreglass, polyester or mineral wool blankets / board. In many instances, the products that provide acoustic absorption also provide thermal insulation. However, the converse is not true, and many thermal insulating materials, such as polystyrene and rigid foams, provide little to no acoustic absorption.

The overall absorption in a space is determined by the performance of the materials and its extent. In simple terms, a 2 m² area of treatment with an Noise Reduction Coefficient (NRC) 0.5 product will provide a similar effect to a 1 m² area of NRC 1.0 product. In shared learning spaces, a large amount of absorption may be required to achieve a suitable reverberation time.



Full ceiling coverage with a high performance absorptive product (minimum NRC 0.85) in addition to wall and extensive use of carpeted floors is required for new school buildings and recommended for the refurbishment of existing buildings.



Other requirements as follows:

- Limit the use of flooring materials that will reflect sound, and increase the amount of absorption in other nearby surfaces to compensate for sound reflection.
- Use a variety of thicknesses of sound absorption materials. Thin products (less than 50 mm) can provide a good level of absorption at high frequencies, but less absorption at low frequencies. Teaching spaces need a variety of treatment thicknesses to absorb high and low frequency sounds.
- Use fabric or perforated metal coverings that are porous so that sound can travel through them to the absorptive material behind. Thick coverings, such as perforated timber or MDF, typically require a perforated open area (>20%) to be effective and are to be used with caution. The use of a thick perforated material is to be restricted to areas where the perforated facing is required for other reasons, such as impact resistance.



Soft materials are to be placed opposite hard surfaces as much as possible to prevent sound bouncing between surfaces.

[Section 5](#) provides further information about absorption material for ceiling, walls and floors.



1.5.2 Toilet facilities

The location of toilets and their configuration within or adjacent to learning spaces may be different depending on the needs of the school. Careful consideration of the requirements for access, security, and visual connectedness will need to be confirmed as part of the project design brief.

Traditionally, school toilet facilities were designed with thin cubicle dividers or screened partitions with hard floor, wall and ceiling surfaces in a centralised large block. In terms of the toilet block enclosure, the designer would have provided a high degree of visual and acoustic insulation intended to isolate the facility from other areas of the school. Typically, these designs would require a wall sound insulation of STC 50 or more to be effective.

However, the materials required to achieve such a high degree of sound insulation reduce the strong visual connection between toilet areas and adjacent spaces. Visual connection is now recognised as critical for passive surveillance and altering toilet behaviour. For more information on the new approach of smaller distributed toilets facilities with self-contained cubicles and lobby areas that can be observed through passive surveillance, refer to the Ministry's [property pages](#) for toilet reference designs.

To ensure teachers and schools have the ability to use this connected learning mechanism, designers will need to design toilet facilities that balance this with acoustic privacy and noise mitigation.

A toilet facility designed with acoustically absorptive ceilings and floors in the lobby, and self-contained toilet cubicles with full-height doors and walls, may be designed with lower lobby to learning space sound insulation. Typically, this can be:

- **STC 40–45 for walls,**
- **STC 35 for fixed glazing,**
- **STC 25 for glazed doors.**

The acoustic treatments help to deaden sound in the lobby area, which can assist with acoustic separation between the toilet facility and the learning spaces.

Where toilet pans are floor mounted, hand dryers are carefully selected low-noise models, and the toilet facility is not adjacent to a noise sensitive area, the sound insulation of walls directly between cubicles and learning spaces can also be reduced to STC 40–45.

Hand dryers are to be placed away from walls directly adjacent to noise sensitive spaces. If hand dryers are mounted on these walls, sound insulation of STC 50 or more may be necessary.

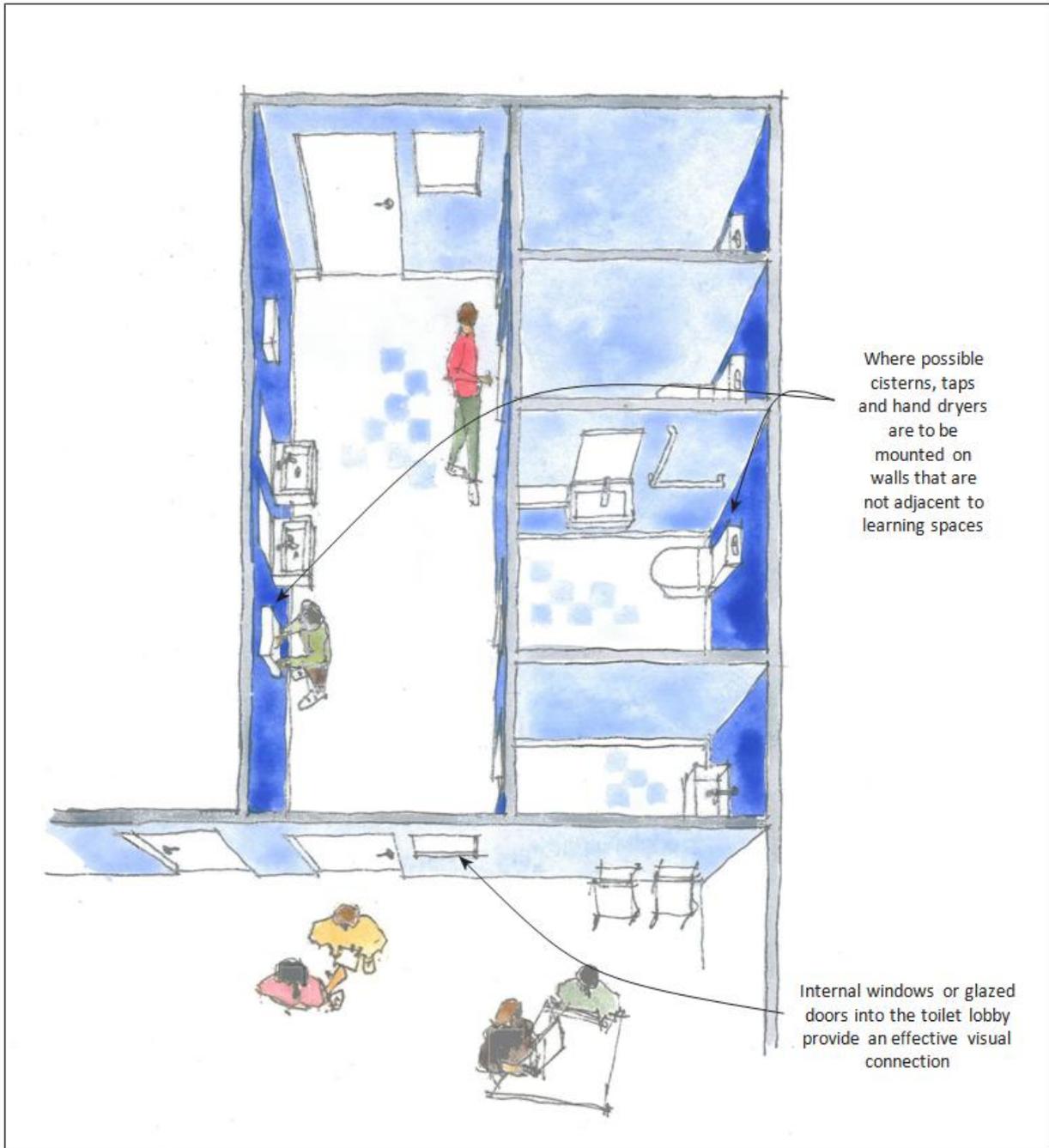


Figure 1-3 Typical toilet block adjoined to a learning space. Hand dryers and cisterns are mounted on walls away from the learning space and passive surveillance is provided into the toilet lobby. Designers are to avoid mounting noise generating fixtures and fittings to bathroom areas on walls that adjoin the learning space.



1.5.3 Inclusive design

Some learners are more affected by noisy learning spaces than others. It is important for schools to be designed to provide learning spaces that are acoustically suitable for all learners, including those with special education needs arising from hearing impairments or learning, emotional or behavioural difficulties. The Ministry's minimum acoustic requirements are set at a level that supports all learners and inclusive education. In some instances, learners may require additional assistance to communicate effectively.

To achieve the best possible acoustic performance for these learners, schools are to aim to:

- minimise internal and external noise sources,
- provide some learning spaces in quiet areas of the school,
- ensure a quiet learning space is always available and easily accessible,
- warn learners of planned fire alarm drills,
- consider installing a sound reinforcement or delivery system that transmits directly to hearing aids,
- limit the noise level of the bell to 75 dB L_{Aeq} within the learning area.



1.5.4 Verifying acoustic performance

Designers are to achieve the recommended level of acoustic performance by following the guidance in this document. Depending on the scope of the project or the complexity of the acoustic issues, they may need to consult an acoustic specialist.

In some cases, the school or designer may also commission a specialist to verify that the post-occupancy acoustic performance of the new learning space meets the requirements set out in the original design brief.

Such instances might be where the designs:

- address a particular external noise problem,
- specify sound-rated partitions,
- are to meet special music or performance standards,
- are to meet specific background noise and reverberation time criteria.

The designer should remain in close communication with the school during the first few months of use of a new learning space. If the school identifies any problems related to the acoustic performance of the design, the services of an appropriate specialist may be required to help address the issues. Depending on the nature of the issue, an educational expert who can advise the school on the best use of the learning space may also be required.

In New Zealand, acoustic consultants may become members of the Acoustical Society of New Zealand (ASNZ). This organisation binds its members to a code of conduct and confirms they are suitably qualified and experienced to carry out specialist acoustic design work. Most members add MASNZ to their business correspondence as a way to indicate their affiliation. For more information, see <http://www.acoustics.org.nz>.

2. Acoustic design considerations for new learning spaces

This section covers:

- [Designing for flexibility](#)
- [Internal noise](#) – considerations for using sound absorbing materials
- [External noise](#) – considerations for school layout planning at master plan stage
 - noise barriers – using physical objects to deflect and reflect
 - glazing use considerations
 - external decks – minimising footfall noise.

When designing a new learning space or extending an existing facility, designers are to consider several factors in order to meet the acoustic performance standards in [Section 1](#).

2.1 Designing for flexibility

The designs of new learning spaces are to carefully balance flexibility and adaptability of use with the acoustic performance required for a range of learning activities. The design should aim to provide:

- a range of spaces to allow teachers and students to choose where they learn,
- degrees of acoustic separation, which will help to reduce distraction from other activities.

A flexible design not only provides a more flexible learning space, it provides excellent scope to achieve good acoustic performance.



Provision of break-out learning areas, with a level of acoustic separation while maintaining flexibility and connectivity should be incorporated in to a flexible learning space.

Traditional cellular classroom designs typically exhibit good acoustic separation. However they can restrict opportunities to collaborate, which limits the range of learning activities and concurrent activities that can take place in the learning space.

More open and connected learning spaces are more flexible and adaptable and provide greater opportunities for collaboration and a broader range of concurrent activities. They also require management or acoustic separation between different learners and learning activities. An acoustic design that ensures adequate absorption of ambient and activity noise levels is crucial.

Movable screens, sliding doors and sliding partitions can be used to divide a larger space into separate areas when required. These can create spatial differentiation in the space; provide nooks and alcoves for small group and individual work. They also provide acoustic 'zoning' in the space, which helps to provide a degree of acoustic separation between activities while maintaining flexibility and adaptability of the space.



Figure 2-1 A break out learning area within a flexible learning space using glass doors. These maintain a visual connection to the adjacent areas, and enable the space to achieve a level of acoustic separation when required.



2.2 Internal noise

To manage internal noise and provide good acoustic performance within a flexible learning space, the design should typically include the following eight key features:

1. Absorptive ceiling treatment
 2. Carpeted floors
 3. Absorptive wall treatments
 4. Adequate spatial volume
 5. Adequate space per student (user density)
 6. Mobile furniture modules
 7. Moveable screens
 8. Sliding and/or hinged partitions
1. An absorptive ceiling treatment (**minimum NRC 0.85**) covering the full ceiling area.



Figure 2-2 A suspended ceiling system with NRC 0.85 tiles to create an acoustic absorption layer on the ceiling.



Figure 2-3 The acoustic absorption layer on a ceiling needs careful design when there are large areas of acoustically reflective floor and wall surfaces and recessed lights and services reduce the amount of absorptive ceiling area.

2. Carpeted floors (except in wet areas) to help control noise, particularly high-frequency noise.



Figure 2-4 Carpets tiles are an effective way to help control noise, the use of acoustic backings further improve their performance.



3. An absorptive acoustic wall treatment (such as acoustically absorbent pinboard) on all available wall surfaces (equivalent to at least 20% of the ceiling area).



Figure 2-5 Use of acoustic pinboard on walls.

4. Adequate spatial volume with as high a ceiling as practicable to maximise the volume of the space and the treatable wall area. Note that without adequate absorptive material this will increase reverberation time.

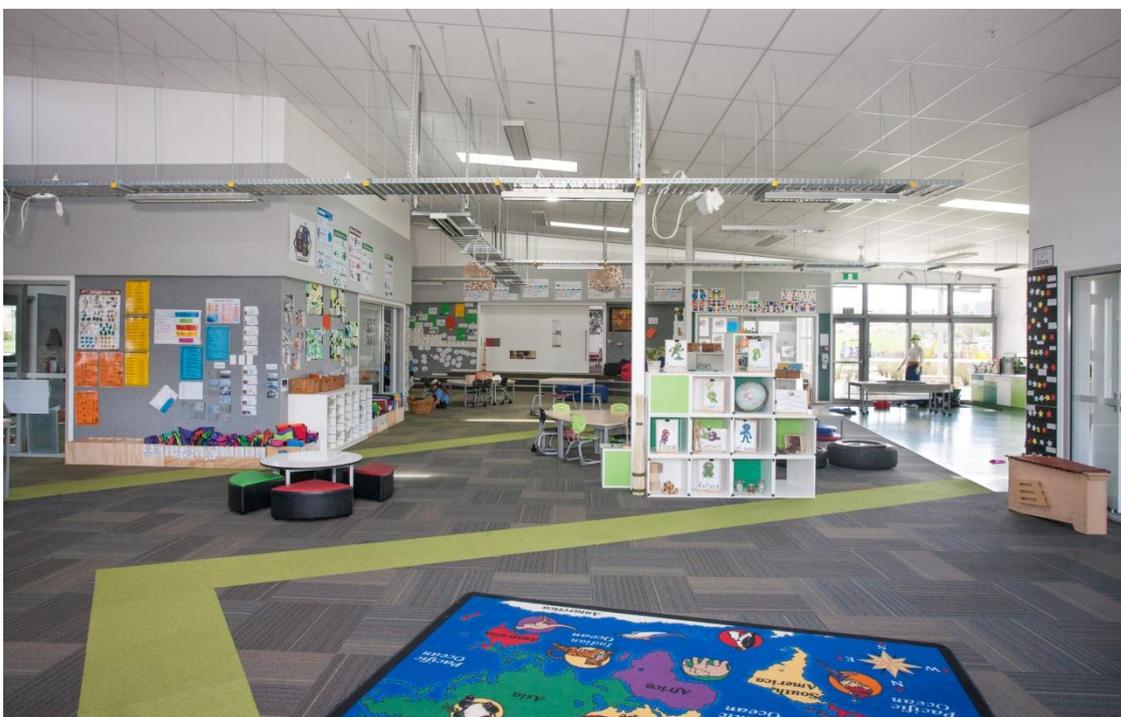


Figure 2-6 High ceilings enlarge the volume of the learning space and increase the wall area available for acoustic treatment.



5. Sufficient floor area for each learner (the design should allow 3-4m² net floor area per learner).
6. Moveable furniture to create break-out spaces within the general areas, and break up large spaces without permanently closing off sections or preventing collaboration and passive surveillance.



Figure 2-7 Students engaged in different learning activities with two teachers using mobile furniture modules to provide visual separation.

7. The use of movable screens or moveable furniture, to define spaces and zones, provide nooks and quiet corners and provide acoustic separation that is easily reconfigurable (screens may be absorptive or reflective, or both depending on the space requirements).



Figure 2-8 Examples of moveable screens used to absorb or reflect sound around nooks and break-out areas. Teachers may want to maintain sightlines, to be effective; screens should be a suitable height and positioned to reduce direct sound paths. Screens should be inherently stable and appropriately designed to ensure they remain upright.



8. Sliding and / or hinged partitions to separate break-out spaces from general areas and break up large spaces when required without permanently closing off sections or preventing collaboration and passive surveillance opportunities.



Figure 2-9 Students engaged in separate learning activities within one connected space separated by moveable sliding partitions.

2.3 External noise – positioning school buildings to optimise acoustics

Learning spaces perform best acoustically when ambient external noise sources are minimised or eliminated. This reduces the amount of acoustic insulation that the learning space requires and makes opening windows for fresh air and outdoor teaching areas more viable.

Traffic on roads is a typical source of ambient noise which will need to be considered. External noise source mitigation is to be considered at the master planning stage. By planning the school so that learning areas are placed as far as possible from noise sources, designs can be more flexible.

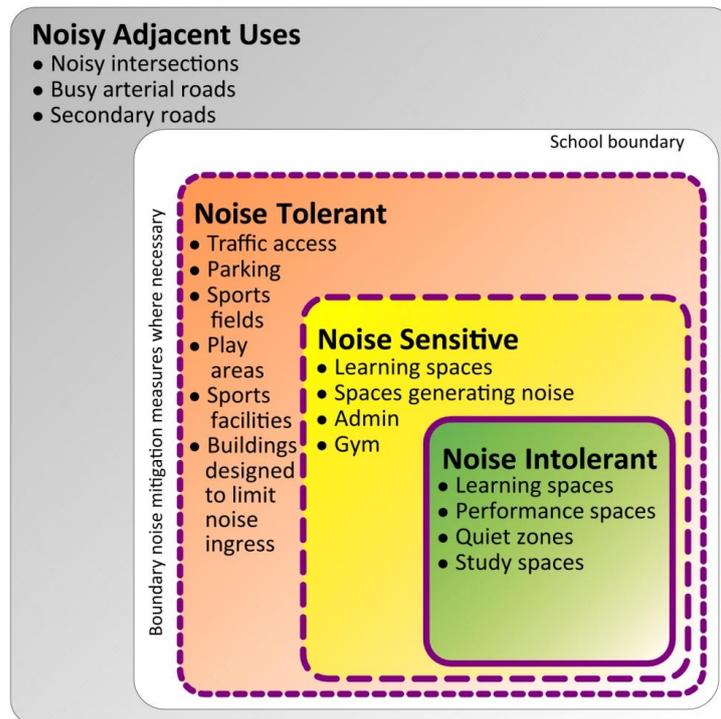


Figure 2-10 Zoning plan to minimise noise in sensitive areas.

It's easier to plan for good acoustics when designing a new building or undertaking extensive refurbishments. When refurbishing, it may be more cost-effective to relocate the learning activities away from the noise source than invest in acoustic controls. This planning is best considered early on as part of the master planning and general layout of a new school or for a significant refurbishment.

Other methods to control external noise may include:

- consulting the local road authority to help reduce the volume of traffic in the area or using quiet road surfaces to decrease traffic noise,
- planning and zoning the site to minimise noise,
- installing noise barriers,
- shielding spaces with other buildings that are less noise sensitive,
- using high mass walls and incorporating earth bunds to deflect noise.

Each strategy has effects on other planning factors and all factors are to be taken into account to achieve an optimal solution.



2.3.1 Noise barriers

A noise barrier is simply a solid structure without gaps that reduces external noise reaching the learning space. They can be constructed from a range of materials. This is often used where distance from external noise sources or other options are unachievable. Any noise barrier is to be carefully positioned as they may also reduce lines of sight and opportunities for passive surveillance afterhours. Things to consider:

An earth bund:

- reflects noise effectively, but noise passes over and around the barrier,
- is relatively expensive,
- takes up space, and
- integrates into the landscape design.

A brick or concrete block noise barrier wall:

- stops noise very effectively, but noise passes over and around the barrier,
- is relatively expensive, and
- provides additional security.

A timber fence noise barrier:

- stops noise effectively, but noise passes over and around the barrier
- is relatively inexpensive, and
- provides additional security.

Trees and shrubs are ineffective as an acoustic barrier.

Timber fence noise barriers should be constructed using solid boarding with a mass per unit area of at least 12 kg/m². There must be no gaps between boards or between the boards and the ground.

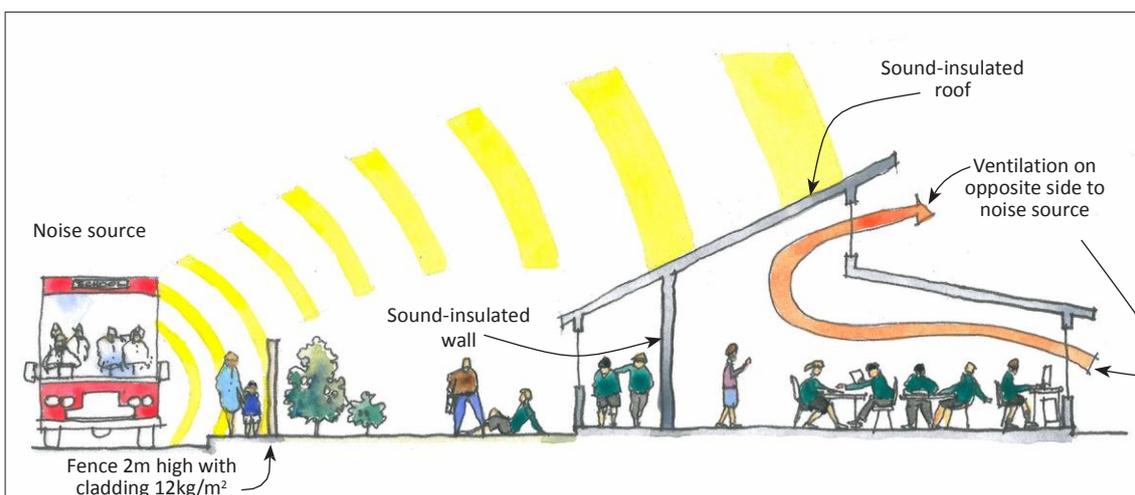


Figure 2-11 Reducing external noise with a solid timber fence and building configuration.

When including any noise barriers into a design it is important to also consider the impact of the possible reduction in passive surveillance. Schools will need to be consulted regarding their strategies for managing crime prevention and vandalism as well.



2.3.2 Glazing

While glass is a desirable material for sliding doors to create separate spaces because it retains visual sightlines between learning spaces, it is also an acoustic reflector. Too much glazing may generate strong reflections of activity noise. This can be reduced by using non parallel surfaces or managed through the placement of furniture or movable screens to disrupt the reflection paths. Alternatively the learning activity could be shifted away from the glass reflector.

2.3.3 External decks

Many schools have learning spaces with exterior timber decks structurally joined to the frame of the building. **To minimise the transfer of footfall noise, designs should structurally isolate the deck from the structure of the learning space and consider using high-mass decks and walkway materials, such as concrete.** This reduces the transfer of low-frequency footfall noise.



For existing learning spaces with structurally connected decks, designers could overlay the deck with high density fibre cement sheet and covering the deck with a quality outdoor carpet. This combination:

- reduces airborne noise,
- increases the slip resistance of wet and icy decks,
- is a relatively moderate-cost solution.

Designers can combine these techniques with other strategies to reduce impact noise such as the addition of a resilient rubber separation under the decking treads.



3. Acoustic design considerations for upgrading existing learning spaces

This section covers considerations for:

- [Organisation of learning activities](#)
- [Addressing common acoustic issues](#)
- [Acoustic upgrade considerations](#)
- [Removing walls](#)
- [Using absorptive materials](#)
- [Adding break out spaces](#)
- [Roof and Ceiling systems](#)
- [Using Movable Screens](#)

The Ministry has produced [Reference Designs for Standard Classroom Blocks](#). These provide examples of upgrades to classroom blocks to create flexible learning spaces.

3.1 Organisation and space planning of learning activities

When planning an upgrade, designers are to consider the range of learning activities that will be undertaken in the space and how they might be arranged within the learning space.

Designers should consider placing wet areas and larger group learning activities at one end of the space, and quiet and individual learning activities at the other end so they can run concurrently within the space in a managed fashion.



3.2 Addressing common acoustic issues

In existing schools it is recommended that designers assess the buildings for any unsatisfactory acoustic characteristics, these should be addressed in the planned modification works. Schools can manage some acoustic issues with simple strategies, such as scheduling noisy activities so they do not coincide with quiet activities or ensuring the mowing of grass areas are outside specified hours.



[Table 3-1](#) identifies some common situations and possible interventions to remedy them.

Table 3-1 Acoustic issues

Indication	Possible interventions
High background noise level from outside sources	Improve acoustic performance of façade, or shield façade from noise source
High background noise level from inside sources	Remove, replace or mitigate sound source(s)
High background noise level from adjacent spaces	Reduce reverberation time by installing absorptive panels/materials within spaces AND Improve acoustic performance between spaces
Excess reverberation	Reduce reverberation time by installing absorptive panels / materials
Teachers find it difficult to project their voices	Reduce internal background noise AND consider acoustic reflectors (specialist advice required)
Some students have hearing impairments	Reduce internal background noise AND Reduce reverberation time AND Consider an assistive listening device (for example, FM / Bluetooth)

Alternatively, depending on the size of the project and the complexity of the issues, schools may consider engaging an acoustic specialist. They will use instruments to measure background noise and reverberation times, and provide design advice and specific remedial measures.

3.3 Acoustic upgrade considerations

When considering an upgrade, schools are to assess the acoustic requirements of their learning spaces to ensure they support the learning activities. These requirements should guide the acoustic design of the upgraded learning spaces. The design should also consider:

- the capacity of the space to support a broader range of teaching practices and learning activities,
- the age and general condition of the building (i.e. whether acoustic improvements form part of a more comprehensive upgrade),
- the projected life of the building,
- the severity of the acoustic issues and the remedial options that are available,
- the cost of improvements against the expected gain (the cost of the ideal solution may be prohibitive and addressing the most critical issues may be more cost-effective).

When upgrading spaces, it is not just the physical space that will change. Schools will identify opportunities, such as co-teaching and collaborative space management, that the improved learning spaces will provide.



When upgrading an existing facility, designers are to consider the performance criteria in [Section 1](#).



Figure 3-1 An example of a flexible learning space upgrade with a large opening to connect two learning spaces in conjunction with improved acoustic absorption.



Generally, an upgrade involves an internal refit of an existing space, often without needing to change the building envelope or existing layout. Designers usually have a range of acoustic and design options available to create an effective learning space within the existing structure.

For example, when working within a predefined floor area, designers may propose several solutions to meet **the recommended 3-4m² of floor area per learner**, such as optimising the use of previously under-utilised areas or incorporating new areas into the footprint of the learning space.



In some cases, the upgrade / refurbishment may place particular emphasis on addressing limitations of the original building design, such as ensuring there is layout separation of teaching areas. These situations may require specific advice from an acoustic engineer to achieve the performance levels described in this guidance.

3.4 Removing walls

Removing a wall between two cellular classrooms provides a more flexible space and increases the collaboration opportunities. The enlarged volume of space increases the reverberation time, but the addition of absorptive materials can counteract this effect. As the level of acoustic privacy that was provided by the wall has been removed, the inclusion of smaller breakout spaces in the overall design may need to be considered.



Figure 3-2 Flexibility in the learning space created by opening up walls to connect adjacent learning spaces.



Figure 3-3 Conversion of a cellular classroom to a flexible learning space by removing cloakroom walls so they can be used as breakout spaces and including bag storage elsewhere within the learning area.



For larger, more open flexible learning spaces, designers should consider leaving a proportion of the existing walls in place where possible. These small wing-walls can aid in breaking up the space. They can create nooks and quiet corners, while providing additional wall area for acoustic treatment without reducing the space's overall flexibility. Using wall features effectively can also enable a range of collaborative teaching and learning possibilities. In some buildings, wing-walls are also required to retain seismic bracing for the structure.

3.5 Adding absorptive materials

Designers should specify highly absorptive acoustic treatments for the full ceiling area and as large a wall area as possible, see [Section 5.3](#) for examples of suitable materials.



The ceiling treatment, usually panels or tiles, should be as thick as practicable (ideally 50mm or more with a noise reduction coefficient of 0.85) to control the low frequency performance of the entire learning space. Designers may also consider using thick acoustic panels as a wall treatment or adding acoustic pinboards. Pinboards are thinner (usually 10–15 mm) and more suitable below 1.8 m high, where they can also be used as display surfaces.

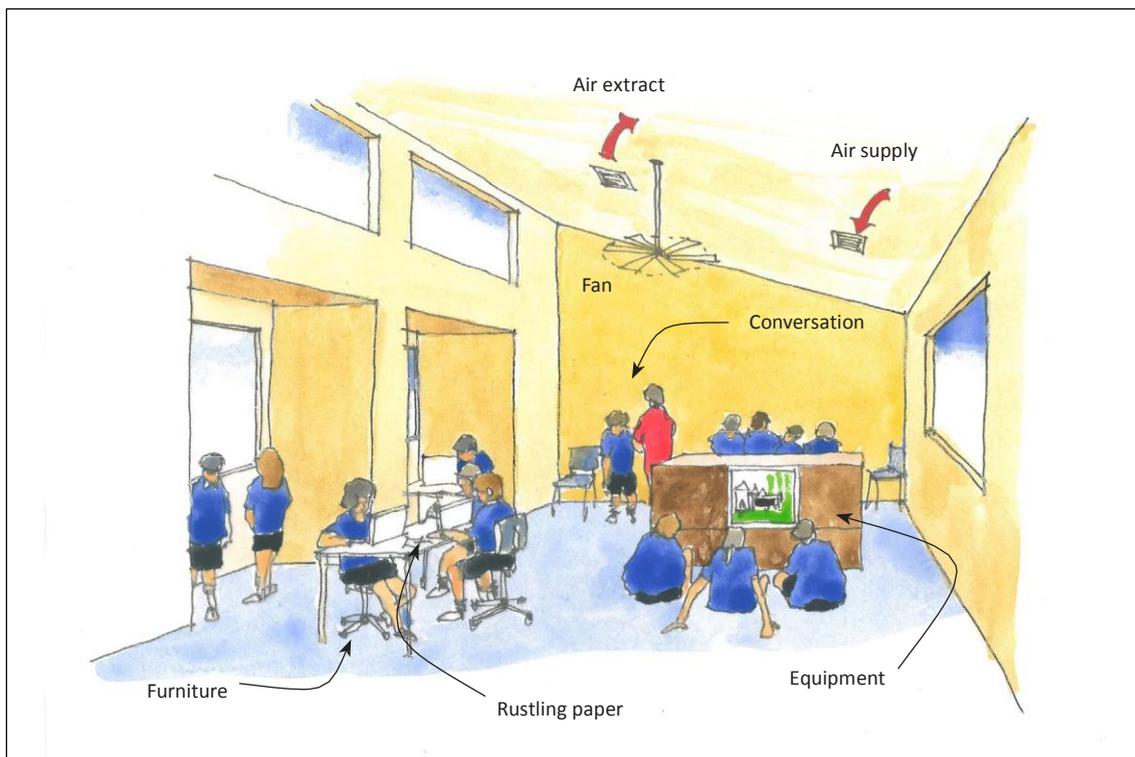


Figure 3-4 Common sources of noise within existing learning spaces.

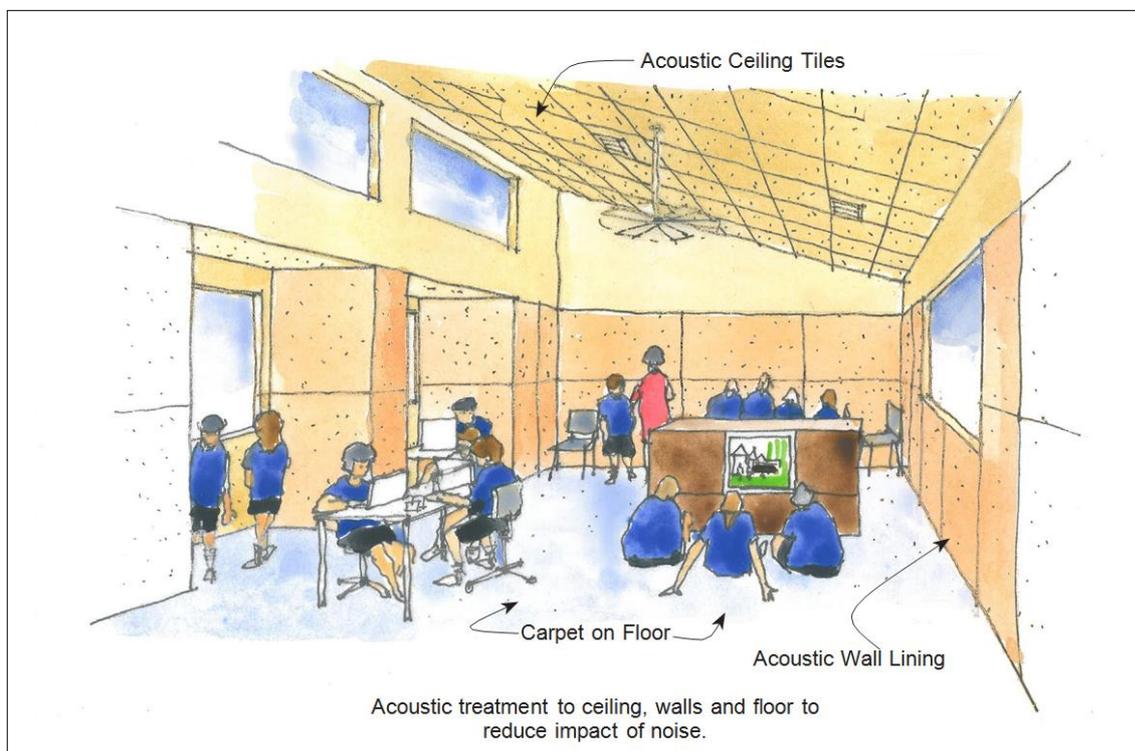


Figure 3-5 Typical acoustic improvements for existing learning spaces.

3.6 Adding break-out spaces

Break-out spaces are an essential part of any flexible learning space. Designers are to ensure there are sufficient break-out spaces to accommodate a wide range of learning activities on a variety of scales.

Break out spaces can be created within the learning space by using moveable screens. This helps maintain flexibility and adaptability within the space and can provide a degree of acoustic separation, when used in conjunction with highly absorptive internal surfaces.

Where learning activities require a higher degree of separation, spaces can be separated with glass sliding doors, which learners can close for increased acoustic privacy while still retaining visual connectivity.

While glass is visually desirable material, as an acoustic reflector it may generate unwanted reflections of activity noise. High levels of acoustic absorption and classroom management can help minimise this noise by lowering the overall background noise levels and modifying behaviour in the space.

Designers should configure learning spaces so learning activities which might be disrupted by the noise is away from glass walls and reflectors. The school may also be able to eliminate the noise source, or place furniture or movable screens within the space to disrupt the reflection paths.



Figure 3-6 Connection of break-out spaces to other learning areas within a flexible learning space providing a degree of acoustic separation while maintaining visual connection.



3.7 Roof and ceiling systems

The roof is an important element in the acoustic performance of a learning space. Flexible learning spaces should use an acoustically absorptive treatment over the entire ceiling area.

If the design removes or replaces the plasterboard with acoustic ceiling tiles, then the designer needs to consider two points.

1. Rain noise will increase. **Designers should discuss with the school the needs to acoustically insulate against rain noise.** If rain noise is an issue, a mass layer should be added elsewhere in the roof system, such as the use of plywood sarking or a warm roof solution that incorporates a mass layer. 
2. If the acoustic ceiling tiles are vapour permeable they will allow the warm internal air to pass through the ceiling tiles. **Note depending on the internal humidity, this may cause condensation to form on the structure and underside of the roof. This situation is to be prevented.** 

Options to reduce rain noise include a layer of plasterboard or similar above the acoustic ceiling tiles or specifying a warm roof system. 

An effective option is to fix the acoustic ceiling tiles directly to, or suspend them below, an existing plasterboard ceiling. This way the mass layer remains intact and the roof will continue to perform well acoustically against rain noise.

Where possible, designers should raise the height of the ceiling as high as practicable as part of the roof upgrade. 

Raising the ceiling height increases the total volume of the learning space, which maximises the wall area available for acoustic treatment and, for the same reverberation time, moderates the acoustic feel of the space.

3.8 Using movable screens

Movable screens are a good way to increase the flexibility of a learning space. Teachers and learners can deploy them to add acoustic separation or alter the size of nooks and quiet areas to suit their learning needs, while maintaining the overall flexibility of the learning space. Screens may be faced with reflective or absorptive material (or one each side), which adds to their flexibility.

Absorptive screens add acoustic separation to the learning space. When positioned correctly, they can break up unwanted reflection paths and give learners a sense of acoustic privacy.

Reflective screens redirect sounds in the learning space. When positioned correctly, they can enhance quiet voices and increase the intelligibility of speech for learners.

Mobile acoustic partitions with absorptive materials should be appropriately designed for the learning spaces. Wheels make them easy to reposition and the flexible sections allow them to be shaped to create separated spaces. Screens can also be used to display artwork and other learning material.

4. Acoustic design for specialist learning spaces

Many schools use specialist learning spaces to support specialist learning activities. Because of the nature of the learning activities these spaces support, many have their own acoustic performance requirements and design solutions.

For example, spaces like halls and gymnasiums usually use hard floor coverings instead of carpet to cater for sports requirements and easy cleaning. However music rooms may use greater sound insulation to prevent ambient noise transfer to other learning spaces.

In each case, designers should ensure the space meets the relevant acoustic performance standards from [Section 1](#) for the learning space in question.

In some schools, dedicated learning spaces, such as science labs, computer labs and wet areas, are part of a larger flexible learning space. **Designers should ensure these spaces are acoustically compatible with the surrounding spaces and the learning environment as a whole.** This should be done while maintaining the space's health and safety and durability requirements.

In some cases, the function of the space means designers cannot follow the general guidance in this document, such as a wet area requiring hard flooring instead of carpet. In this situation, designers should minimise hard floor coverings to those areas where required. The use of soft floor coverings will improve acoustics and allow more flexible use of the space.

Not all learning activities associated with technology, science and music produce lots of noise, although designing for flexibility at the design stage will maximise the benefit to the school.

4.1 Halls / Multipurpose spaces

Many schools have a large hall which is used for a variety of learning activities, such as assemblies, lectures, theatrical productions, musical recitals, gymnastics and physical education. Each of these activities has its own acoustic requirements and ideal reverberation time.

Designers should be conservative and provide a more controlled acoustic environment for halls used for multiple activities. Designers should allow for a lower reverberation time to ensure the space is fit for the range of activities and purposes it will be used for.

Table 4-1 shows the recommended ambient sound levels and reverberation times for halls / multipurpose spaces from AS/NZS 2107:2000 Acoustics - Recommended design sound levels and reverberation times for building interiors.

Table 4-1 Ambient sound levels and reverberation times for halls / multipurpose spaces

Size of hall	Ambient sound level (dB)	Reverberation time (s)
Up to 250 seats	30–40	0.6–0.8
More than 250 seats	30–35	Refer to curve in Figure 4-1

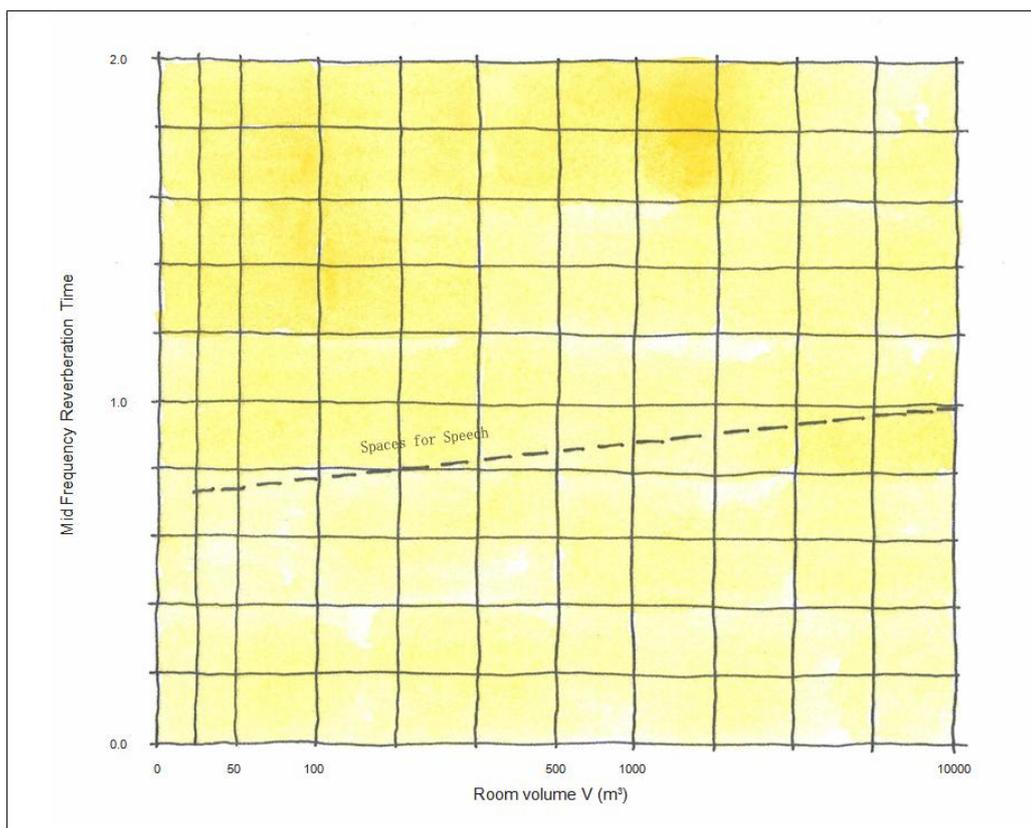


Figure 4-1 The ideal reverberation time is dependent on the volume of the space.

The most common acoustic problems with halls used for multiple purposes are a high level of background noise and excessive reverberation, usually owing to hard surfaces and a large number of windows.

To address these issues and improve the acoustic performance of multipurpose spaces, designers should:



- add acoustic absorption,
- reduce reflections that cause echoes, particularly for performers on stage,
- review the shape of the hall to see if it supports its purposes, note designers can modify the acoustic shape of an existing hall using reflector panels, positioned so they project unamplified sound to the audience,
- review the methods of ventilating, heating and cooling, and weighing up the benefits of opening windows for fresh air versus mechanical systems,
- review the sound amplification system to ensure it is fit for purpose, and position the loud speakers to avoid acoustic issues, such as feedback and echoes,
- use absorptive floor coverings suitable for multipurpose use,
- use surfaces that are impact resistant especially end walls and ceilings.



Figure 4-2 Example of flocked carpet flooring in a multipurpose gymnasium space to help improve acoustic absorption.

4.2 Gymnasiums

Because of the learning activities they support and the need for hard wearing surfaces, gyms tend to be noisy places with high reverberation times. This is to be expected.

- ✔ If the intention is to use the space for a variety of learning activities, then consideration of some acoustic control is advisable. **Options include applying acoustically absorptive treatment to the entire area of the gymnasium ceiling and all available wall surfaces (equivalent to at least 20% of the ceiling area).**
- ✔ **The surface of the acoustic treatments in gymnasiums should be suitably robust and impact resistant.** Some specialist acoustic products are impact rated (see [Section 5](#) for examples), or alternatively designers can use traditional acoustic absorbers protected behind a perforated facing material. Flocked carpet and elastomeric floor covering systems may also be appropriate for reducing footfall noise and providing a softer court surface.



Figure 4-3 A school gymnasium with impact resistant wall surfaces at low levels and impact resistant acoustic absorptive panels above and onto the ceiling.



Figure 4-4 A school gymnasium with impact resistant acoustic wall surfaces at low levels and using acoustic absorptive panels on the ceiling so the gym can also accommodate learning activities such as Kapa Haka.

Section 4

4.3 Libraries



Traditionally, libraries are quiet places. [Table 4-2](#) shows the recommended ambient sound levels and reverberation times for libraries from *AS/NZS 2107:2000 Acoustics - Recommended design sound levels and reverberation times for building interiors*.

Table 4-2 Ambient sound level and reverberation time for libraries



Type of library	Ambient sound level (dB L _{Aeq})	Reverberation time (s) - RT _{MF}
Separate building	40-45	0.4-0.6

Designers should use these acoustic performance standards for separate libraries housed in a dedicated building. For library spaces that are part of a larger flexible learning space, the acoustic performance may be relaxed, enabling designers to provide acoustic separation where required with movable screens or furniture.

When planning a bespoke library building, designers should consider:

- locating it in the school’s quiet zone,
- including sufficient acoustic insulation to isolate it from nearby noise sources,
- using acoustically absorptive internal finishes (see [Section 5.3](#) for examples).



Figure 4-5 An open plan library with adjacent break-out spaces. The curved wall helps break up sound paths.



4.4 Music facilities

School music facilities require acoustic flexibility, because of the range of learning activities that they support. They should support learners singing and playing a wide range of instruments.

Designers can achieve good acoustic performance in a music facility by providing:



- sufficient acoustic insulation to prevent ambient noise getting in and activity noise getting out of the space'
- good quality sound within the space, by eliminating unwanted acoustic artefacts, such as reverberation and echoes.

When designing a new music facility, designers should place a high priority on acoustic performance and consider consulting an acoustic specialist early in the planning stage of the design.



Schools also use several types of specialist spaces for musical learning activities, including:

- small practice spaces (for individuals or small groups of learners (see [Figure 4-6](#))),
- learning spaces (for learning music theory and occasional live or amplified music performances (see [Figure 4-7](#))),
- ensemble spaces (for small group performances and rehearsals),
- performance spaces (for small and informal presentations),
- recording studios (to accommodate musicians during recording sessions (see [Figure 4-8](#))).

It's important to remember these spaces are part of the spatial provision for teaching and learning for the whole school. The designer needs to balance the purpose-built acoustic performance against the potential use of spaces for other learning activities, the ability to support collaborative teaching and learning, and the ability for teachers to ensure passive surveillance.

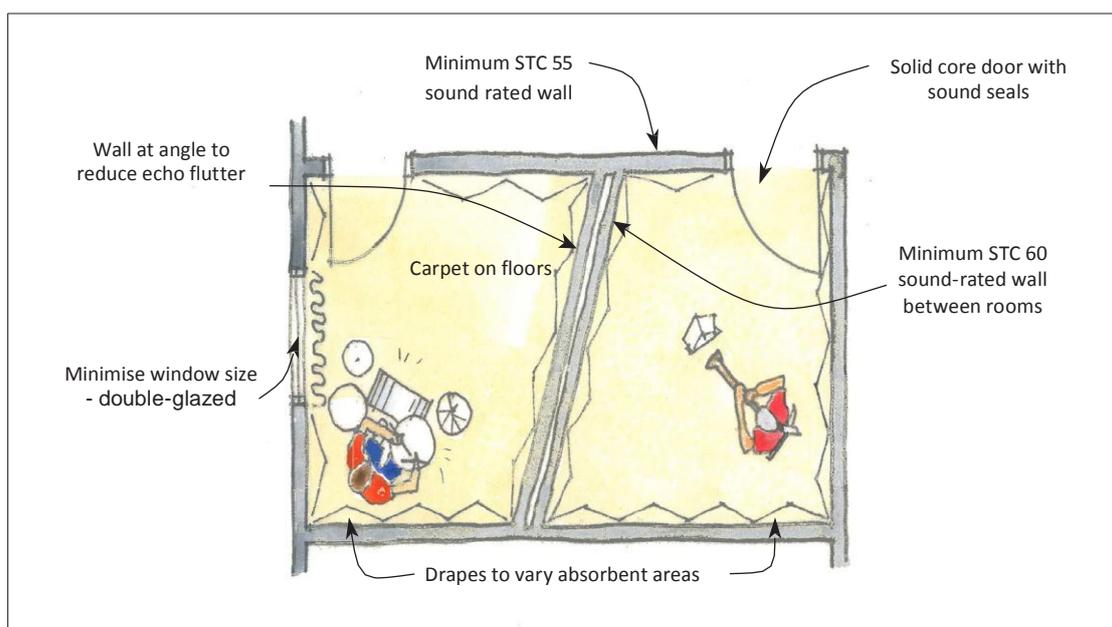


Figure 4-6 Small music practice spaces (area from 8–10 m²).

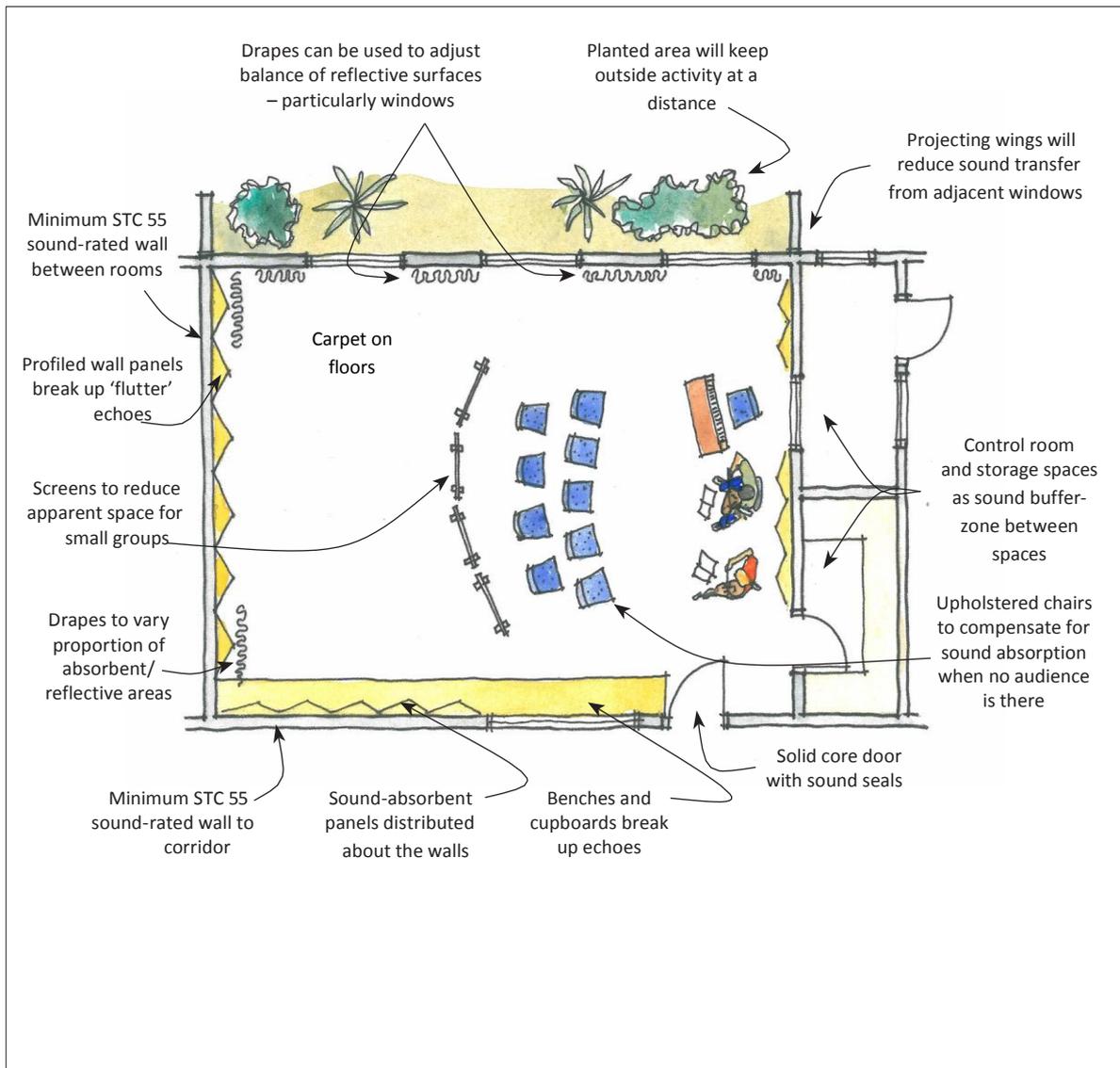


Figure 4-7 A range of possible acoustic treatments for larger music spaces.

These learning spaces may also have special requirements, including:

- accommodating a large number of people,
- supporting a specific type of music,
- normal or amplified music,
- high sound levels (and how this affects other learners).

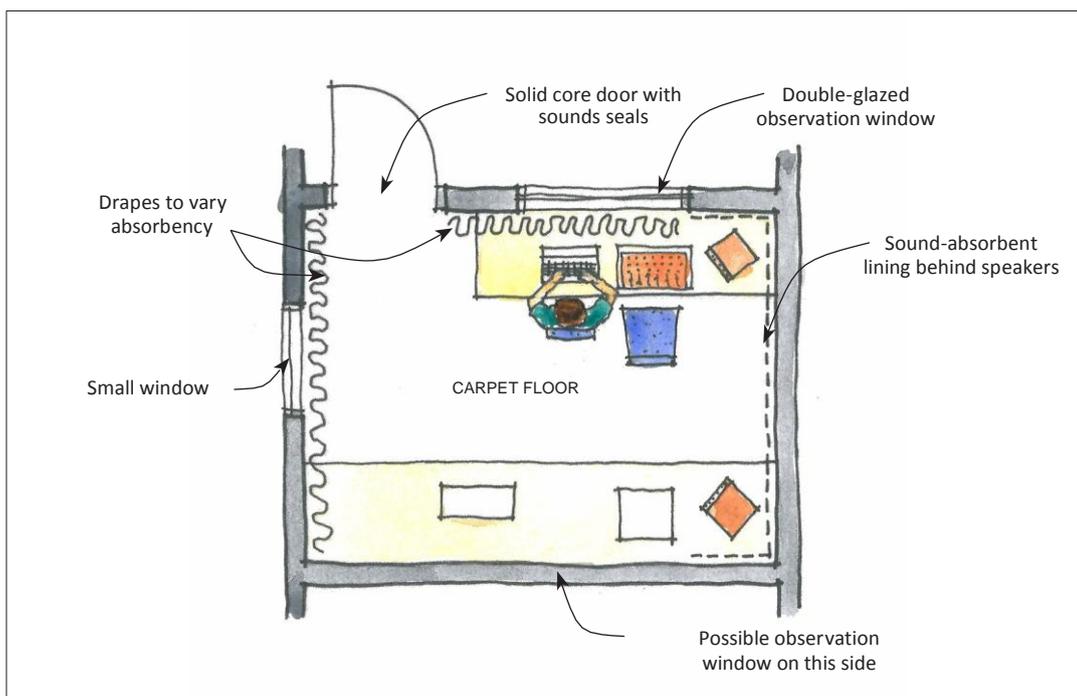


Figure 4-8 A musical recording and control room.

4.4.1 Sound insulation

To achieve the recommended acoustic performance standard of STC 60, music facilities and learning spaces should not be located directly adjacent to other types of learning spaces. Refer [Table 1-3](#).

This will not always prevent activity noise because some instruments produce high levels of sound. Selecting doors and windows is an important consideration in the acoustic design of a music facility, and designers should select them so they do not compromise acoustically rated wall systems.

4.4.2 Sound quality

The sound quality in a music space depends on the duration and distribution of the echo or reverberation time. Reverberation time is affected by the size of the room and its total area of absorption. To achieve good sound quality, designers should combine the volume and proportions of the space to optimise the reverberation characteristics.

To create a successful music space, designers will need to balance three acoustic parameters:

1. Ambient noise must be low enough that learners can hear the full range of sound.

To be effective learning spaces the design of the music space should meet the ambient noise performance given in [Table 4.3](#).

Table 4-3 Recommended ambient noise levels for music rooms

Type of room	Ambient noise level (dB)
Music room with audio system	35
Music practice room or ensemble room	30
Recording and control room	25



2. The music space should be free from noticeable echoes, flutter echoes or any other effects which confuse or distort the sound.

Generally, designers should ensure music spaces:

- have a higher than average ceiling height -at least 3 m for small spaces and proportionately higher for larger spaces,
- avoid square or nearly square plan proportion,
- have a length × width × height proportion that cannot be expressed as a ratio of whole numbers (for example, a space with dimensions 10.5 m × 7 m × 3.5 m has a ratio of 3:2:1 and is therefore not advisable),
- avoid curved walls or ceilings because they can focus sound,
- have one non-parallel wall and / or sound diffusion elements to break up regular echo patterns and flutter echoes (see [Figure 4-6](#)).



3. The reverberation time of the space should suit the music activity in the space.

For most schools, it is impractical to dedicate music spaces to particular types of music, so spaces should be flexible enough to support a range of different music.

Designers can add flexibility by specifying heavy curtains, which teachers and learners can deploy to vary the reverberation time and alter the ratio of reflective and absorbent surfaces (see [Figure 4-7](#)).

With the exception of large performance halls, designers should carpet all music spaces to control reverberation and suppress noise from footfalls and moving furniture.

[Table 4-4](#) shows typical proportions and recommended reverberations times for different of music spaces. **As a general guide, the design of music spaces should meet these reverberation times.**

Table 4-4 Recommended reverberation times for music performance

Type of space	Area (m ²)	Height (m)	Reverberation time (s) - RT _{MF}
Rehearsal hall	250–550	3.7–7.6	1.0–1.4
Music rooms	54–91	3.0–3.5	0.5–0.6
Ensemble rooms	16–50	2.7–4.0	0.8–1.2
Small practice rooms	6–10	2.7–3.0	0.3–0.5
Recording and control rooms	8–15	2.7–3.0	0.3–0.7





4.5 Technology spaces - high noise

Learning activities in technology spaces can produce very high noise levels and designers are to ensure that these spaces are sufficiently sound insulated to prevent the noise disturbing learners in other areas.



When assessing the sound insulation requirements of a technology space, designers are to establish:

- what learning activities will take place,
- the type of equipment learners will use,
- the noise levels these will generate.

Schools and designers have several strategies available to them to reduce the noise from technology spaces. They can:

- locate noisy technology spaces as far from quiet areas as possible,
- use buffer areas, such as storage spaces, to reduce sound transmission,
- invest in low-noise equipment,
- install noisy equipment correctly to minimise sound transfer,
- maintain equipment correctly,
- reduce the reverberation time of the space by introducing absorptive surfaces wherever possible. For example, rubber floor tiles, acoustic baffles on walls and ceilings,
- install very noisy equipment in sound-insulated enclosures,
- add further sound insulation around noisy areas,
- schedule noisy learning activities to minimise disturbance.

Technology spaces often include auxiliary equipment, such as dust and fume extractors, which are an additional source of noise and will need to be addressed in the acoustic design.



Figure 4-9 An example of a high-noise technology learning space.

4.6 Technology spaces - moderate noise



Other learning activities in technology spaces may not generate such high noise levels and designers should consider the amount of acoustic insulation in these spaces accordingly.

Learning activities, like art and graphics classes, food production and textile technology, can still be moderately noisy because they are likely to have hard surfaces for ease of cleaning, which increases



reverberation time and which may lead to the [café effect](#). Designers should reduce the reverberation time to less than 1 second. In art spaces where there are likely to be large display areas, they should consider reducing reverberation time by using high performing acoustic ceilings and pinboard wall treatments.



Designers should also consider separating out learning activities that produce noise, and installing carpets, where appropriate, to increase sound absorption and reduce impact noise. Where carpet is not practical, a foam-backed vinyl is a suitable alternative, with ordinary vinyl under heavy equipment.



Figure 4-10 Technology spaces present challenging acoustic environments.

4.6.1 Hazardous noise

Schools should ensure teachers and learners are not exposed to harmful levels of noise.

The Ministry of Business, Innovation and Employment's *Approved Code of Practice for the Management of Noise in the Workplace* provides recommended guidelines for exposure to noise.



Generally, the threshold is 85 dB L_{Aeq} for no more than 8 hours.

If the exposure time is less, then the allowable level can be proportionately higher. The Ministry continues to review guidance and best practices in order to comply with the [Health and Safety at Work Act 2015](#) and supporting regulations.



Schools are to provide appropriate hearing protection to all teachers and students who are exposed to loud noise. Specialist music teachers may be exposed to high levels of noise for long periods and schools should ensure they have musician's earplugs fitted.



5. Acoustic performance of typical construction types

5.1 Typical Sound Transmission Class (STC) ratings

5.1.1 Internal sound insulation

Doors and windows can represent a weak link in the sound insulation of sound-rated partitions and reduce the overall acoustic insulation performance.

As the area of doors and windows is generally significantly smaller than the area of the walls, a door or window with a lower STC rating than the STC rating of the wall can be selected without compromising the overall (combined) sound insulation performance of the entire partition.

Specialist advice is to be sought to determine if a reduction in the sound insulation performance of doors and windows is appropriate for the learning activities to be carried out within the spaces.



5.1.2 Fixed walls and partitions

[Table 5-2](#) through to [Table 5-8](#) provide internal sound insulation performance for a range of wall construction arrangements. Options using normal and high-density plasterboard are also provided.

Table 5-1 Typical plasterboard densities

Plasterboard type	Minimum density (kg/m ³)
Normal	640
High-density	960

Table 5-2 Acoustic insulation performance of lightweight walls (STC 30–34)

Construction	STC 30–34
10 mm plasterboard 90 mm timber stud 10 mm plasterboard	
10 mm plasterboard 64 mm steel stud 10 mm plasterboard	

Table 5-3 Acoustic insulation performance of lightweight walls (STC 35–39)

Construction	STC 35–39
13 mm plasterboard 90 mm timber stud Fibreglass or polyester absorptive blanket in the wall cavity ¹ 13 mm plasterboard	
13 mm plasterboard 64 mm steel stud Fibreglass or polyester absorptive blanket in the wall cavity ¹ 13 mm plasterboard	

¹ At least 75 mm thick and a density of 9 kg/m³

Table 5-4 Acoustic insulation performance of lightweight and masonry walls (STC 40–44)

Construction	STC 40–44
13 mm plasterboard 20 mm timber / steel strapping at 600 mm centres 140 mm filled concrete blocks or 110 mm precast concrete 20 mm timber / steel strapping at 600 mm centres 10 mm plasterboard	
13 mm plasterboard 92 mm steel stud Fibreglass or polyester absorptive blanket in the wall cavity ¹ 13 mm plasterboard	
13 mm plasterboard 90 mm timber stud Fibreglass or polyester absorptive blanket in the wall cavity ¹ 2×13 mm plasterboard	
13 mm plasterboard 20 mm timber / steel strapping at 600 mm centres 190 mm filled concrete blocks or 150 mm precast concrete 20 mm timber / steel strapping at 600 mm centres 13 mm plasterboard	

¹ At least 75 mm thick and a density of 9 kg/m³

Table 5-5 Acoustic insulation performance of lightweight and masonry walls (STC 45–49)

Construction	STC 45–49
13 mm plasterboard 20 mm timber / steel strapping at 600 mm centres 140 mm filled concrete blocks or 110 mm precast concrete 20 mm timber / steel strapping at 600 mm centres 13 mm high-density plasterboard	
2×13 mm high-density plasterboard 90 mm timber stud Fibreglass or polyester absorptive blanket in the wall cavity ¹ 1×13 mm high-density plasterboard	
13 mm plasterboard 92 mm steel stud Fibreglass or polyester absorptive blanket in the wall cavity ¹ 2×13 mm plasterboard	
13 mm high-density plasterboard 92 mm steel stud Fibreglass or polyester absorptive blanket in the wall cavity ¹ 13 mm high-density plasterboard	
13 mm high-density plasterboard 20 mm timber / steel strapping at 600 mm centres 140 mm filled concrete blocks or 110 mm precast concrete	

¹ At least 75 mm thick and a density of 9 kg/m³

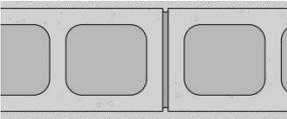
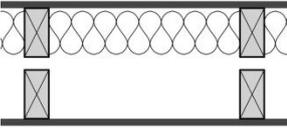
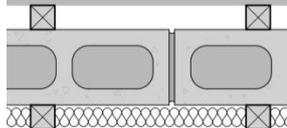
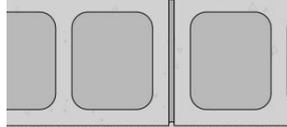
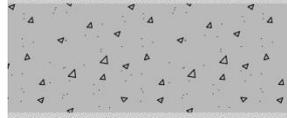


Table 5-6 Acoustic insulation performance of lightweight and masonry walls (STC 50–54)

Construction	STC 50–54
1×13 mm plasterboard 90 mm double timber / steel studs forming 200 mm cavity Fibreglass or polyester absorptive blanket in the wall cavity¹ 1×13 mm plasterboard	
140 mm filled concrete blocks (paint/plaster finish)	
110 mm precast concrete (paint/plaster finish)	
2×13 mm high-density plasterboard 90 mm timber stud Fibreglass or polyester absorptive blanket in the wall cavity¹ 2×13 mm high-density plasterboard	
13 mm high-density plasterboard 20 mm timber / steel strapping at 600 mm centres 190 mm filled concrete blocks or 150 mm precast concrete	
2×13 mm plasterboard 92 mm steel stud Fibreglass or polyester absorptive blanket in the wall cavity¹ 2×13 mm plasterboard	

¹ At least 75 mm thick and a density of 9 kg/m³

Table 5-7 Acoustic insulation performance of lightweight and masonry walls (STC 55–59)

Construction	STC 55–59
190 mm filled concrete blocks (paint / plaster finish)	
150 mm precast concrete (paint / plaster finish)	
1×13 mm high-density plasterboard 90 mm double timber / steel studs forming 200 mm cavity Fibreglass or polyester absorptive blanket in the wall cavity ¹ 1×13 mm high-density plasterboard	
1×13 mm plasterboard 90 mm double timber / steel studs forming 200 mm cavity Fibreglass or polyester absorptive blanket in the wall cavity ¹ 2×13 mm plasterboard	
13 mm plasterboard 45 mm timber / steel strapping at 600 mm centres 140 mm filled concrete blocks or 110 mm precast concrete 45 mm timber / steel strapping at 600 mm centres Fibreglass or polyester absorptive blanket in the wall cavity ¹ 13 mm plasterboard	
240 mm filled concrete blocks (paint / plaster finish)	
200 mm precast concrete (paint / plaster finish)	

¹ At least 75 mm thick and a density of 9 kg/m³



Table 5-8 Acoustic insulation performance of lightweight and masonry walls (STC > 60)

Construction	STC > 60
2×13 mm plasterboard 90 mm double timber / steel studs forming 200 mm cavity Fibreglass or polyester absorptive blanket in the wall cavity ¹ 2×13 mm plasterboard	
2×13 mm high-density plasterboard 64 mm double steel studs forming 150 mm cavity Fibreglass or polyester absorptive blanket in the wall cavity ¹ 1×13 mm high-density plasterboard	
140 mm filled concrete blocks (paint / plaster finish) 45 mm steel stud Fibreglass or polyester absorptive blanket in the wall cavity ¹ 13 mm plasterboard	
13 mm plasterboard Fibreglass or polyester absorptive blanket in the wall cavity ² 45 mm timber / steel strapping at 600 mm centres 140 mm filled concrete blocks or 110 mm precast concrete 45 mm timber / steel strapping at 600 mm centres Fibreglass or polyester absorptive blanket in the wall cavity ² 13 mm plasterboard	

¹ At least 75 mm thick and a density of 9 kg/m³

² 45 mm thick, 9 kg/m³

5.1.3 Operable walls

The laboratory performance of operable walls can be reasonably high (STC 45–50), however, the sound insulation performance achieved on-site is likely to be no greater than STC 35.

Operable walls are not recommended where the learning spaces requires acoustic insulation performance greater than STC 40.



High performance acoustic operable walls are heavy and hard to operate. Because of this they may not be used correctly. They also remove sight lines; users on either side of the wall tend to forget about users on the other side of the wall. This can result in higher noise levels being generated on either side of the wall and the wall being ineffective in providing adequate sound separation.

5.1.4 Glazing

Table 5-9 Acoustic insulation performance of glazed walls

Construction	STC
6 mm monolithic glass	31
16 mm monolithic glass	35
10.38 mm acoustic laminate glass	35
12.76 mm acoustic laminate glass	38
<i>Insulating glazing unit</i> 8.76 mm acoustic laminate 12 mm air cavity 6 mm monolithic	40
<i>Insulating glazing unit</i> 8.76 mm acoustic laminate 50 mm air cavity 6 mm monolithic	45
<i>Insulating glazing unit</i> 8.76 mm acoustic laminate 100 mm air cavity 6.76 mm acoustic laminate	50
<i>Insulating glazing unit</i> 8.76 mm acoustic laminate 200 mm air cavity 12.76 mm acoustic laminate	55

5.1.5 Doors

Table 5-10 provides the expected sound insulation performances for a range of door construction arrangements.



Hollow core doors are not to be used in new schools as they are easily damaged and provide limited acoustic separation.

Table 5-10 Acoustic insulation performance of door systems

Door	Perimeter treatment	STC
Hollow-core door	No seals	< 20
	Compression seals to head, threshold and jambs	20
Solid core door (24 kg/m ²) <i>(Vision panels are acceptable in doors provided glazing is at least 10.38 mm acoustic laminate)</i>	No seals	20–25
	Compression seals to head, threshold and jambs	30
Glass doors (minimum glazing of 10.38 mm acoustic laminate)	No seals	20–25
	Compression seals to head, threshold and jambs	30
Proprietary acoustically rated doors ¹	Proprietary frame and compression seals to head, threshold and jambs	35–43
Proprietary acoustically-rated double connector door ¹	Proprietary frame and compression seals to head, threshold and jambs	45
Lobbied solid core doors (24 kg/m ²) ¹	Compression seals to head, threshold and jambs	55–60

¹ Designers need to consider the users when specifying high performance doors. Young users or those who have high physical needs may struggle to operate doors with seals. Designers should arrange spaces to minimise the requirement for these doors.



5.1.6 Floors and ceilings

Table 5-11 and Table 5-12 provide the expected sound insulation performance for a typical range of masonry and lightweight floor arrangements in conjunction with a range of ceiling constructions.

Table 5-11 Acoustic insulation performance of masonry floor constructions

Floor and ceiling construction	STC
120 mm concrete	50
100 mm concrete Suspended or direct fix lightweight ceiling tiles ($\geq 2 \text{ kg/m}^2$) or absorptive blanket	50–54
100 mm concrete Suspended plasterboard (10 mm) backed ceiling tile	50–54
100 mm concrete Suspended 13 mm plasterboard ceiling	55
100 mm concrete Fibreglass or polyester absorptive blanket in the ceiling cavity ¹ Suspended plasterboard (10 mm) backed ceiling tile	60–64
100 mm concrete Fibreglass or polyester absorptive blanket in the ceiling cavity ¹ Suspended 13 mm plasterboard ceiling	> 65

¹ At least 75 mm thick and a density of 9 kg/m^3

Table 5-12 Acoustic insulation performance of lightweight floor constructions

Floor/ceiling construction	STC
25 mm timber floorboards fibreglass or polyester absorptive blanket in the ceiling cavity ¹ Suspended 13 mm plasterboard ceiling	50
25 mm timber floorboards fibreglass or polyester absorptive blanket in the ceiling cavity ¹ Suspended 2×13 mm plasterboard ceiling	55

¹ At least 75 mm thick and a density of 9 kg/m^3

5.2 Impact sound insulation - Typical IIC ratings for common construction types

Impact sound insulation depends upon the impact performance of the floor finish. The mass of the ceiling and inclusion of an absorptive blanket within the ceiling cavity also significantly affects the overall performance.

5.2.1 Masonry floor slabs

Table 5-13 outlines the expected IIC performance for a range of typical floor finishes in conjunction with a 100 mm concrete floor slab and a variety of ceiling arrangements. This table provides options to achieve IIC 50 or higher.

While a concrete floor slab is a more effective floor construction for impact sound insulation.

Designers choosing concrete floors will have to consider seismic performance of the supporting structure and are to confirm this with the project engineer.



Table 5-13 Impact sound insulation performance for variety of floor finishes and floor and ceiling construction types

Floor finish	Floor/ceiling construction	IIC achieved
Carpet (5 mm pile height 650 g/m² pile weight)	100 mm concrete Suspended plasterboard (10 mm) backed ceiling tile	50–54
	100 mm concrete Suspended ceiling tiles, ≥ 2.0 kg/m ²	55
	100 mm concrete Suspended 13 mm plasterboard ceiling	55
	100 mm concrete Fibreglass or polyester absorptive blanket in the ceiling cavity ¹ Suspended plasterboard (10 mm) backed ceiling tile	60–64
	100 mm concrete Fibreglass or polyester absorptive blanket in the ceiling cavity ¹ Suspended 13 mm plasterboard ceiling	65
Cushioned vinyl Rubber Flocked vinyl (min. ΔL_w 18)	100 mm concrete Suspended ceiling tiles, ≥ 2.0 g/m ²	50
	100 mm concrete Suspended plasterboard (10 mm) backed ceiling tile	50
	100 mm concrete Suspended 13 mm plasterboard ceiling	50
	100 mm concrete Fibreglass or polyester absorptive blanket in the ceiling cavity ¹ Suspended plasterboard (10 mm) backed ceiling tile	55–60
	100 mm concrete Fibreglass or polyester absorptive blanket in the ceiling cavity ¹ Suspended 13 mm plasterboard ceiling	60–65

¹ At least 75 mm thick and a density of 9 kg/m³

5.2.2 Lightweight timber floors

Lightweight timber floors require a carpet with cushioned underlay in order to achieve a rating of IIC 55. Lightweight timber floors also exhibit a low frequency thump (due to the hollow nature of the floor construction), which is not quantified in the IIC rating system. Designers using lightweight timber floors on upper stories will need to account for this.

5.3 Sound absorbing materials – typical treatment options

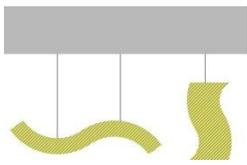
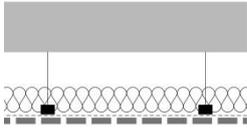
5.3.1 Ceiling materials

The ceiling provides the bulk of absorption within flexible learning spaces. The ceiling provides the largest surface area and is less susceptible to damage than wall treatments. A highly absorbent ceiling is also desirable to reduce reflections between spaces. A range of treatments is provided in Table 5-14.

Take care not to reduce the total area of acoustic absorption through recessed light fittings, heating panels and other services. Consider suspending services to maintain the total area.



Table 5-14 Typical ceiling treatment options

Construction arrangement	Typical product options	Note
	15–25 mm fibreglass or mineral fibre ceiling tile in T grid. Minimum NRC 0.85.	Lightweight tiles often provide limited sound insulation performance. Rain noise or impact noise from above needs consideration.
	50 mm fibreglass ceiling tile with plasterboard backing. Minimum NRC 0.85.	The use of a plasterboard backing provides improved sound insulation performance. A thicker absorptive component is required to provide adequate low frequency absorption.
	50 mm high-density blanket (> 35 kg/m ³) direct fixed to the underside of the slab above.	An absorptive blanket provides negligible sound insulation performance. Impact noise from above needs careful consideration. Adequate thickness is required to provide sufficient low frequency absorption.
	Fibreglass or mineral fibre ceiling tile in direct fix grid. Total depth of system ≥ 50 mm. Minimum NRC 0.85.	Adequate thickness is required to provide sufficient low frequency absorption.
	Floating fibreglass or mineral fibre acoustic baffles hung horizontally or vertically.	Can provide useful absorption but needs to be used in a high density pattern to provide absorption equivalent to full ceiling coverage.
	Perforated / slotted / slatted timber or MDF with an open area > 15% and acoustic fabric and / or 50 mm acoustic blanket behind.	It is difficult to achieve a performance greater than NRC 0.8 with perforated timber and MDF products. These types of products may provide useful additional performance, for example, as feature panels or where impact resistance is required.
	Perforated metal with an open area > 15% with acoustic fabric and / or 50 mm acoustic blanket.	Perforated metal ceilings provide limited sound insulation performance and rain noise or impact noise from above will need to be mitigated.



5.3.2 Wall materials

It is important that absorption is incorporated on the space’s vertical surfaces. Insufficient absorptive treatment on the walls will enable sustained reflections and reverberation between the walls. Resulting in excessively long reverberation times, possible echoes, sound colouration and flanking of screens, despite significant ceiling treatment.

To reduce this effect in flexible learning spaces, acoustic absorption should be added to every available wall area at least equivalent to 20% of the absorption provided on the ceiling should be incorporated on the walls.



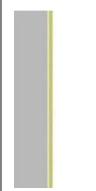
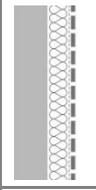
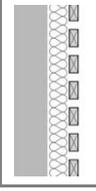
The wall surfaces in learning spaces are often used for displays and reference material, and it is essential that lower portions of the wall are robust. Extensive use of thick acoustic wall panels at low levels is often impracticable. A combination of acoustically absorptive pin boards at low levels and proprietary acoustic wall panels at higher levels is recommended. For learning spaces with significant

areas of glazing, almost all of the wall surfaces will require acoustic treatment to suppress reflections off the glass.



In specialist learning spaces, such as gymnasiums and technology spaces, impact resistance is important, and fibrous blankets may need to be covered with a rigid perforated facing.

Table 5-15 Typical wall treatment options

Construction arrangement	Typical product options	Anticipated performance	Note
 NRC 0.4	10–15 mm acoustic pin board	NRC 0.4	
 NRC 0.9	50 mm thick acoustic wall panel	NRC 0.9	
 NRC 0.5-0.8	Perforated / slotted / slatted timber or MDF with an open area > 15% and acoustic fabric or 50 mm acoustic blanket behind	NRC 0.5–0.8	A compromise may be required between open area and structural integrity when used at low levels.
 NRC 0.7-0.85	50×25 timber battens over 50 mm acoustic blanket. 33–50% open area.	NRC 0.7–0.85	Timber slats can provide an effective screen that provides significant impact resistance while providing high performance absorption.

5.3.3 Floors

Floor material selection need to be considered in conjunction with other surface finishes and performance requirements of the space.



Where practical, the Ministry recommends learning spaces be covered with a medium pile carpet, with pile depth greater than 5 mm.

Designers are to consider such things as:

- ease of cleaning,
- it is a high traffic area,
- will the floor get wet,
- are children going to be sitting on the floor.

Hard floor areas reflect sound and provide little to no sound absorption. For this reason, wet and specialist areas, should be limited. They require specific design consideration to incorporate them effectively in a Flexible Learning Space.



5.4 External sound insulation – typical performance

5.4.1 Rain noise

While absorptive materials reduce RT they are typically inadequate by themselves to stop impact sound like rain noise through a ceiling. In such cases the addition of mass will be required to achieve the Ministry’s performance requirements for RT and impact sound.

Minimising high rain noise levels depends on geographic location rainfall, material selection and the design of the roof. Designers have a range of options, including soft roof coverings (such as torch-on membranes), sarking, cavity insulation, and an acoustic ceiling (such as resiliently hung or multi-layer plasterboard).

Table 5-16 outlines the expected rain noise level in a typical flexible learning space for a range of roof and ceiling constructions to achieve a rain noise level of NC 40 or lower. These levels are based on a 10m×20m×4m space, with a reverberation time of 0.7 s, and a rainfall rate of 20 mm/hr.



Table 5-16 Acoustic performance of roof constructions against rain noise

Roof	Cavity absorption	Ceiling	Internal sound level achieved
Profiled steel cladding ²	Fibreglass or polyester absorptive blanket ¹	Suspended 13 mm plasterboard ceiling	NC 40
Profiled steel cladding ² and 12 mm plywood sarking	Fibreglass or polyester absorptive blanket ¹	Suspended 13 mm plasterboard ceiling	NC 31
Profiled steel cladding ² and 12 mm plywood sarking	Fibreglass or polyester absorptive blanket ¹	Suspended 10 mm plasterboard ceiling tiles with a resilient backing	NC 35
Profiled steel cladding ² and 12 mm plywood sarking	Fibreglass or polyester absorptive blanket ¹	Suspended ceiling tiles with mass per unit area > 3.5 kg/m ²	NC 40
Profiled steel cladding ²	Fibreglass or polyester absorptive blanket ¹	13 mm plasterboard fixed directly to the underside of the purlins AND suspended ceiling tiles with mass per unit area ≥ 2.0 kg/m ²	NC 38

¹ At least 75 mm thick and a density of 9 kg/m³

² Most standard profiles except 400 mm through section.



6. Glossary & references

6.1 Glossary

Acoustical Society of New Zealand (ASNZ) An incorporated society for people with a professional or other involvement in acoustics. People with the society grade ‘Member’ have had their qualifications and experience ratified by the society, and are entitled to use the post-nominal letters MASNZ.

Ambient noise level Sound level in an unoccupied space. Sources may include ventilation systems, computer fans etc, or outdoor sources such as traffic, aircraft or playground activity.

Building consent A consent for building work to be carried out in accordance with plans and specifications approved by a city or district council.

Café effect Increase in activity noise due to people raising their voices to be heard over other activity noise, also known as the Lombard effect.

Decibels (dB) Measurement unit of sound pressure level. Typically, A-weighted to match the frequency response of average human hearing. Measurements of sound pressure are usually time averaged, so are expressed as L_{Aeq} levels in dB.

Flexible learning space (FLS) A space that facilitates flexible use and learning opportunities, including collaborative and co-teaching practises. The learning space may be made up of a range of spaces, including more open plan spaces that may be divided by furniture and moveable screens, and breakout or withdrawal spaces.

Flutter echo Successive repetitive echoes caused by sound bouncing backwards and forwards between two parallel walls.

Impact insulation class (IIC) Acoustic rating of a building element (usually a floor / ceiling system) in terms of its ability to prevent impact sound transmission from footfalls etc. A higher number is better.

Impact sound Sound caused by an impact, such as footsteps, which is heard in an adjacent space.

Impact sound pressure level ($L_{nT,w}$) The average sound pressure level in a specific frequency band in the receiving space when the floor under test is excited by a standardised impact sound source.

Innovative learning environment (ILE) A school environment which encourages collaboration and inquiry, both for learners and teachers, and allows teachers to teach in the style that best suits the needs of their diverse learners. These school environments are capable of evolving and adapting as educational practices evolve and change – thus remaining future focused

Noise criterion (NC) A rating method used to assess continuous background noise and assign a single value. (Noise sources such as rain noise are commonly assessed using this method). A lower number is better.

Noise reduction coefficient (NRC) Rating of a material’s sound absorption properties. A material with NRC 0.7 absorbs 70% of the incident sound. A number closer to 1 will absorb more incident sound.



Open-plan office effect A decrease in activity noise due to people lowering their voices in a highly absorptive space with low reverberation time.

Reverberation The building up of sound energy in a space, promoted by reflections off its interior surfaces.

Reverberation time (RT) Time taken for the reverberant sound to decrease by 60 dB after the generation of the sound has stopped, known as a (T_{60}) test. Used to describe the basic acoustic quality of a space. Reverberation time is related to a space’s volume and its area of sound absorptive material.

Reverberation time (RT_{MF}) The reverberation time expressed as the mid frequency average, used to describe the reverberation time over the mid frequency band (500Hz, 1000Hz and 2000Hz). Measured using the same T_{60} criteria for each frequency and then being averaged.

Signal-to-noise ratio (SNR) The difference (in decibels) between a sound that is desired to be heard (such as the teacher’s voice) and other sound (such as activity noise).

Sound absorption The process of converting sound energy into heat energy. Sound absorptive materials are used to reduce RT and noise build-up, and prevent unwanted reflections.

Sound-flanking paths The routes by which sound can pass through or around a building element, for example, through a door duct or floor and around a partition or screen. Flanking paths compromise the acoustic performance of wall and floor systems so should be avoided as much as possible.

Sound pressure level (L_p) A logarithmic ratio of a sound pressure measured at distance, relative to the threshold of hearing ($20 \mu Pa_{RMS}$) and expressed in decibels.

Sound transmission class (STC) Acoustic rating of a building element (such as a wall or floor) in terms of its ability to prevent airborne sound transmission. A higher number will prevent more sound being transmitted.

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Appendix A Acoustic concepts

A.1 Understanding sound

To better assess the acoustics of a learning environment, it is helpful to understand how teachers and learners perceive sound and how it behaves in different spaces.

A.1.1 Sound levels

Sound is transmitted by pressure waves moving through the air. Sound pressure level (L_p) is a measure of the amplitude (strength) of these waves. It is expressed in decibels (dB), which is a logarithmic value based on the ratio of a sound compared with the threshold of human hearing.

An L_p of 0 dB is the quietest detectable sound for someone with perfect hearing, while 140 dB is on the threshold of pain, although people can have an adverse reaction to much lower levels.

Because the scale is logarithmic, a sound level increase of 3 dB is just noticeable, while an increase of 10 dB is perceived as twice as loud. [Table 6-1](#) shows typical sound levels in a school environment.

Table 6-1 Typical sound levels in schools

dB	Source and distance (where applicable)
16	Threshold of human hearing (person with good hearing)
20	Quiet recording space
35-40	Quiet unoccupied classroom
60-70	Busy classroom with lots of activity – normal voice at 1m
80-90	Vacuum cleaner – person shouting at 1m
100	Very loud music (maximum recommended by the World Health Organisation)



A.1.2 Frequency

As well as sound level, learners also perceive sounds at different frequencies. Low frequencies are deep and boomy, like those produced by a bass drum or diesel engine. High frequencies are shrill and piercing, like those produced by a piccolo or a siren.

Frequency is measured in Hertz (Hz), which is defined as the number of pressure waves per second. The human hearing range is about 20 Hz to 20 kHz (20–20,000 pressure waves per second) and we are most sensitive to sounds between 250 Hz and 8 kHz, which corresponds with the frequency range of speech. [Figure 6-1](#) shows the typical frequency and sound pressure produced by a several common sound sources.

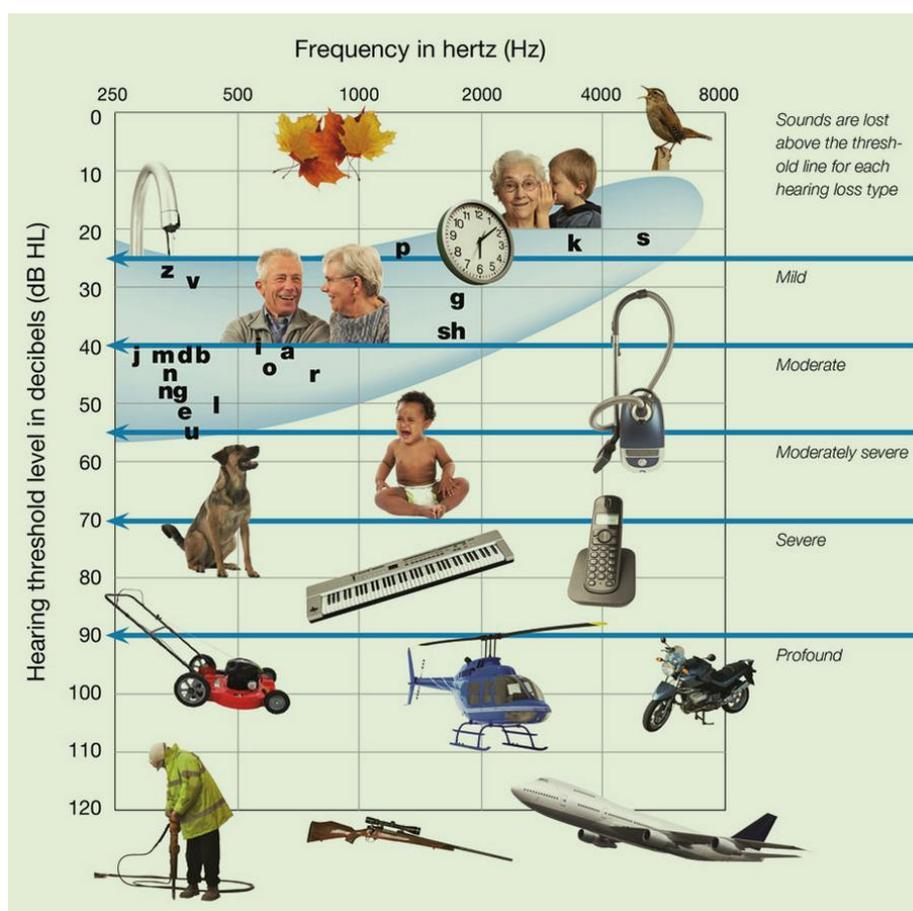


Figure 6-1 Common sources of sound showing the frequency and sound pressure they typically produce.

A.1.3 How surfaces affect sound

From an acoustics point of view, the surfaces within a learning environment can be divided into three broad categories – reflective, absorptive and diffuse. Each type of surface has a different effect on sound. Surfaces usually display a combination of these properties, but they tend to be categorised based on their predominant characteristic.

A.1.4 Reflective surfaces

Reflective surfaces allow sound to bounce around, so they tend to propagate noise. Reflective surfaces are typically made from hard materials, and include concrete floors, glass doors and plasterboard walls and ceilings.

A.1.5 Absorptive surfaces

Absorptive surfaces do not allow sound to reflect, so they will tend to remove sound from a learning environment. Absorptive surfaces are usually made from softer materials, and include fibrous batts, carpet, curtains and a range of loosely woven fibrous materials. Often these are manufactured as tiles, for example acoustic ceiling tiles.

Depending on the characteristics of the material, some adsorptive surfaces remove more sound at certain frequencies. Thick absorbers (> 50 mm) and absorbers over an air-gap tend to be more effective at low frequencies, whereas thinner absorbers (such as carpet or 10–15 mm acoustic pinboard) work better to absorb higher frequencies.



Figure 6-2 Acoustically absorptive panels suspended above a learning space to reduce reverberation and echo.

A.1.6 Diffusive surfaces

Diffusive surfaces scatter sound in many different directions at once. They typically keep a space sounding 'live', while eliminating the type of reflections that can cause echoes.

Diffusive surfaces are usually made from hard materials, but are shaped to give them diffusive properties. Any non-flat surface will provide diffusion, such as plaster formwork, hard furniture and timber slats.



A.1.7 Noise

Noise is unwanted sound. It can come from any sound source (machinery, outside activities, other learning groups) and becomes noise when it's not the intended source of sound (like a teacher speaking or a discussion within a group).

The level of noise in an unoccupied learning space is called the ambient noise level, commonly measured in time-averaged A-weighted decibels ($\text{dB } L_{\text{Aeq}}$).

Similarly, the level of noise in an occupied learning space and generated by learning activities, such as speech, music, multimedia, footsteps, moving and dropping of objects and furniture, is known as the activity noise level. Activity noise is always generated by the people and activities taking place in the learning space.

Research indicates that ambient noise levels in New Zealand learning spaces starts at 28 dB and activity noise levels can be greater than 70 dB in some schools.

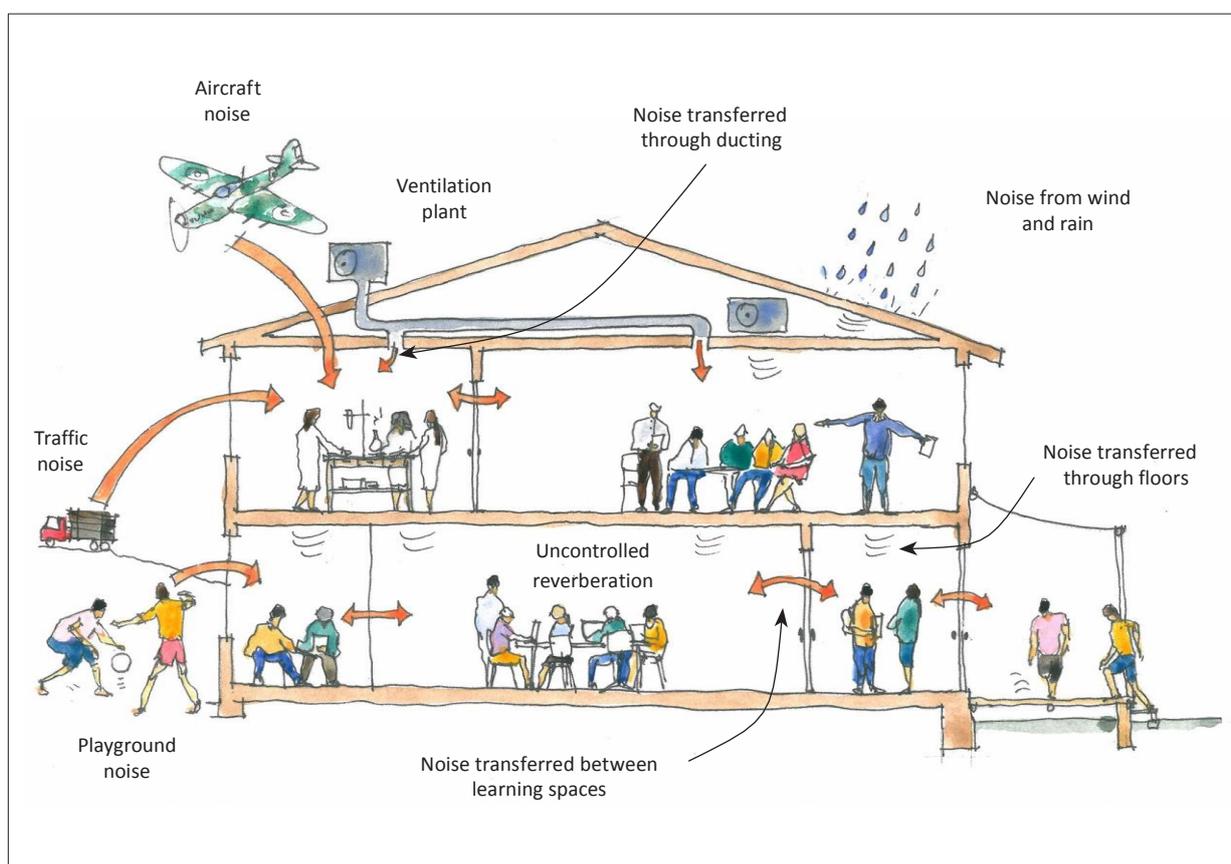


Figure 6-3 Common sources of intrusive noise in learning spaces.

A.1.8 Exterior noise

Exterior noise is a type of ambient noise generated outside the learning environment. Sources include:

- noise generated outside the school (such as road traffic and building construction),
- noise generated on school grounds (such as grass cutting and sports events).



Exterior noise always enters the learning space by passing through a buildings walls, roof, floor or windows.

Schools should improve the acoustic performance of their learning spaces to minimise the impact of exterior noise, but any acoustic improvements are to be considered in conjunction with other important characteristics of the environment that support learning.

For example, schools that use opening windows to provide their learning spaces with adequate ventilation may need to manage exterior noise in other ways. While this can be difficult to do for off-site noise sources, many schools report that the greatest exterior noise is generated on school grounds by activities under their control, such as lawn mowing, and activity noise from sports fields and other outdoor learning spaces.

A.1.9 Interior noise

Interior noise is a type of ambient noise generated inside the learning environment. Sources include:

- noise transferred from separate learning spaces (such as learning activities occurring in adjacent learning spaces, which do not share coordinated management of activities)
- noise created within the learning space(s) (such as fans, computers, printers and other electronic devices and equipment).

Interior noise is often more subtle than exterior noise, but can have a greater impact on the acoustic performance of the learning space.

Some younger learners can be more easily distracted by interior noise because they have not yet developed the ability to selectively ignore ambient sounds.

A.1.10 Reverberation time

In an open outdoor space, the sound pressure (L_p) decreases as the listener moves further from the source of the sound. In an enclosed indoor space, sound bounces off any reflective surfaces and L_p rises and falls as the sound bounces around the space. This effect is heard as reverberation.

Once a source stops making sound, the time it takes for the last bouncing sounds to fade away is called the reverberation time (RT). Reverberation time is measured in seconds (s), and ideal values range from 0.3 s for a recording studio, to 2.5 s for a concert hall, and up to 8 s for a cathedral.

Learning environments with shorter reverberation times are perceived as acoustically ‘dead’ and controlled, while those with longer values are more ‘live’ and ‘echoey’ (reverberant).

The reverberation time depends on two factors:

1. the volume of the space (a larger volume means it takes longer for the sound to reach the reflective surfaces, such as walls and ceiling) and
2. the size of the space’s absorptive surfaces (larger absorptive surfaces remove more sound from the space with each bounce, making the sound fade more quickly).

When the reverberation time is too long, reflected sounds start to interfere with the original sound source, and learners begin to have difficulty understanding speakers, holding conversations, and hearing other sounds in the learning space.



Because sound bounces, reflected sound always travels further than direct sound to reach the learner. If the extra distance sound travels is less than 8 m, the reflected sounds can reinforce the original sound, enhancing intelligibility of the sound for the learner. If the extra distance is more than 12 m, the learner may hear a distinct echo interfering with the sound.

Some schools have intentionally introduced reflective surfaces into learning spaces to enhance teachers voice for didactic teaching (refer [Figure 6-4](#)). However if these reflective surfaces are poorly placed they can reduce the overall absorptive content of the space and increase background noise (refer A.1.11 below)

Many learning activities within flexible learning spaces typically have no ‘front of class’ and didactic teaching is only one of many teaching practices used within the spaces. Designers should note that acoustically tuning the space for a specific activity may limit its use for other learning activities and teaching practices. The use of reflective surfaces for voice projection should only be employed in specialist learning spaces where didactic teaching is carried out for the majority of the time that the space is used.

See [Section 1](#) for recommended maximum levels of reverberation in schools.

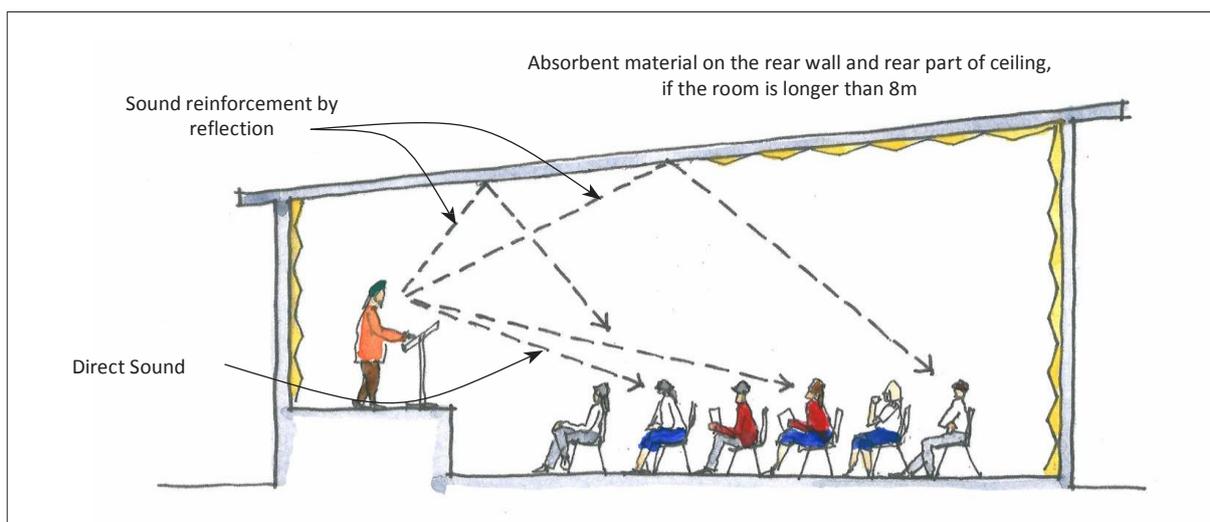


Figure 6-4 Acoustically reflective surfaces create multiple paths for sound to reach the listener. Because reflected paths are longer than the direct path, reflected sound takes slightly more time to travel and the listener hears the delay as reverberation. Reflectors carefully positioned closer to the speaker can enhance voice projection and make listening easier, but the opposite is true if placed incorrectly.

A.1.11 Acoustic effects

Poor acoustic design or lack of acoustic treatment can lead to the combination of significant ambient noise and a long reverberation time creating a situation known as the ‘café effect’. This occurs when one speaker raises their voice to be heard above the ambient noise, so other speakers raise their voices to be heard, so the first speaker raises their voice again, and so on.

The result is an extremely noisy environment, which makes it difficult to understand what people are saying. The effect becomes worse with longer reverberation times. In some schools this effect may be noticeable in spaces that have all hard surfaces, for example plasterboard ceilings and vinyl floors.

In open-plan spaces, highly absorptive surfaces help reduce the ambient noise level and reverberation time, deadening the sound. Users unconsciously notice this and alter their behaviour by lowering their voices, further decreasing the level of background noise. This is known as the 'open-plan office effect'. The effect facilitates collaborative work practice, especially when used in conjunction with rooms where individuals and groups can break out and participate in group activities.

These principles are applicable when designing spaces to facilitate [innovative learning environments](#) where flexible learning spaces connect many groups of learners together in a variety of learning activities. Schools need to ensure their more open plan flexible learning spaces are acoustically designed to prevent the [café effect](#) occurring and encourage both the benefits of and associated good behaviours of an open plan environment.

This can be achieved by designing the learning spaces with highly absorptive ceilings and wall treatments, and ensure the learning spaces are flexible enough that individuals and small groups have breakout spaces for separate learning activities with a level of acoustic separation which prevents direct line-of-sight sound transmission. This can be readily achieved with moveable screens, or sliding or hinged panels.



Figure 6-5 Acoustic floor, wall and ceiling treatments, with visually connected break-out spaces.



A.1.12 Sound insulation

One way to mitigate the effects of noise is to reduce its transmission into the learning environment with sound insulation. Sound insulation is the ability of a material to prevent sound passing through it. Materials with high mass, such as concrete, brick and multi-layered plasterboard have the best sound insulation properties.

Sound insulation is rated using either:

- sound transmission class (STC),
- level difference (D_w).

Refer to [Section 1](#), [Table 1-2](#) and [Table 1-3](#) for sound insulation requirements in schools.

While sound absorption is very important in flexible learning spaces, sound insulation between learning groups within the space is less critical than it was in traditional classrooms. Users tend to adjust their behaviour through the 'open-plan office effect' and high levels of absorption in adjoining spaces lowers the ambient noise levels in both spaces. Together, these reduce the amount of direct sound being created that could interrupt learning activities in an adjacent space.

Moveable screens or glass sliders can offer some benefit to further prevent noise transfer between adjacent learning activities, and visually linking the activity spaces.

A.1.13 Impact insulation

Impact insulation is the ability of a material to prevent vibrations (such as footfalls and dropped objects) from transmitting through a floor system. Resilient materials, such as carpet, thick rubber and cork have good impact insulation properties.

It is rated using either:

- impact insulation class (IIC),
- impact sound pressure level ($L_{nT,w}$).

Refer to [Section 1](#) for recommended levels of impact insulation in schools.



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