Acoustics in Schools is intended to be a tool for architects, interior designers and other design professionals who work to improve school environments. Commissioned by Ceiling and Interior Systems Construction Association (CISCA) and prepared by the InformeDesign Research Desk at the University of Minnesota, the white paper is an introduction to the acoustical issues commonly confronted on school projects. Practical design responses to these issues are then presented in practitioner-friendly language. The following is an abridged version of the white paper. To view the entire paper, including a glossary of terms and a listing of references, visit www.cisca.org.

CISCA
Ceilings & Interior Systems Construction Association

Acoustics in Schools

Why acoustics matter

Classroom acoustics are an important, often neglected, aspect of the learning environment. Up to 60% of classroom activities involve speech between teachers and students or between students, indicating the importance of environments that support clear communication.

Yet, classrooms in the United States typically have speech intelligibility ratings of 75% or less, meaning every fourth spoken word is not understood.

Who benefits from improved acoustics?

- Children, especially those younger than 13 years of age, have an undeveloped sense of hearing, making the impacts of background noise on hearing, comprehending and learning more pronounced for them than for adults.
- Students with temporary illnesses causing mild hearing loss.
- Students with learning, attention, or reading deficits are more adversely affected by poor acoustic conditions than the average student.
- Students speaking English as a second language require significantly better acoustic conditions to hear the teacher.
- Hearing-impaired students require a significantly better acoustic environment.
- Teachers benefit because teachers speaking in loud or reverberant classrooms may have to raise their voices, leading to increased stress and fatigue.

Fundamentals of sound and acoustics

When a sound wave contacts a surface such as a wall in a closed room, the energy and direction of the sound is altered. These alterations are perceived as sound reflections and reverberations, which can affect auditory perceptions.

Adults' perceptions of speech intelligibility are often better than children's perceptions. As a result, adults should not rely solely on their own subjective assessments of acoustic conditions in a classroom.

The three primary acoustic problems in schools are background noise, reverberation time and signal-to-noise ratio.

Background noise

Background noise is any auditory disturbance within a room that interferes with what a listener wants to hear.

Classrooms typically have speech intelligibility ratings of 75% or less, meaning every fourth spoken word is not understood.

Excessive background noise in schools has a negative impact on student learning and performance. As a result, background noise in unoccupied classrooms should not exceed 30-35 A-weighted decibels or dB(A). (A-weighted decibels better reflect the response of the human ear, which is less sensitive to low and high frequencies.)

Major sources of background noise include noise from outside the school building (road traffic, air traffic), outside the classroom (hallways, adjacent classrooms), or inside the classroom (HVAC systems, instructional equipment).

Reverberation time

Reverberation time is the time it takes for sound to decay once the source of sound has stopped.

Reverberations occur when sound waves strike surfaces such as floors, walls and ceilings in a room and are reflected back onto the space. Reverberation will continue until all the sound waves have been absorbed or have dissipated. Reverberation times should not exceed 0.6 seconds in general classrooms.

Reducing reverberation time to acceptable limits will help with speech intelligibility. The added absorption will also reduce the overall sound level in the room without adversely affecting the signal-to-noise ratio.

Signal-to-noise ratio

Signal-to-noise ratio (SNR) is the ratio of desired sound (teacher's voice) to undesired background noise (mechanical equipment). Larger numbers denote better acoustic performance. SNRs should meet or exceed +15 dB(A) in all locations of a classroom.

Signal-to-noise ratios generally become less favorable for hearing as the distance between the speaker and the student increases. Thus, different locations in a classroom may have different SNRs. For example, SNRs are typically lowest at the back of a classroom or near a noise source such as an air conditioner.

Acoustical design considerations for general classrooms

Speech intelligibility decreases when background noise increases or when there are long reverberation times.

To improve the acoustic environment of schools, designers need to focus on controlling background noise, reverberation times and signal-to-noise ratios.

Reducing external background noise

To help limit the impact of external background noise on the classroom environment, consider these measures:

SITE PLANNING Locate critical listening environments such as core classrooms away from external noise sources (roads, railways, mechanical units, etc.).

LANDSCAPE DESIGN Use trees, earthen banks, and concrete barriers around school buildings to reduce the amount of external noise entering classrooms.

STRUCTURAL CONSIDERATIONS Install pads underneath the school's supporting structure to reduce structurally-borne background noise.

EXTERIOR WALL CONSTRUCTION Install dense, insulated external walls with few openings (doors, windows, etc.) near sources of high external noise. Fill cracks or gaps in exterior walls with elastic bonding to improve noise isolation.

DOORS AND WINDOWS Seal all gaps in window and door frames. Hang acoustically-treated curtains or draperies in front of windows to reduce the proliferation of external noises into classrooms.

Reducing interior background noise

To help limit the impact of interior background noise on the classroom environment, consider these measures:

NOISE FROM ADJACENT SPACES Separate particularly sound-sensitive spaces, such as classrooms, from both external and internal sources of noise (playgrounds, gymnasiums, music rooms, etc.) by using non-acoustically sensitive areas (corridors, storage areas, etc.) as buffer spaces.

Stagger classroom doors in hallways to create longer, less direct paths for noise to travel between rooms.

PARTITION WALL CONSTRUCTION Use additional layers of gypsum in partition walls and ensure their gap-free construction. Use dense, acoustically treated doors with rubber or gasket seals to reduce sound transmission. We recommend insulation for absorption of sound energy in the wall partition cavity.

To improve the acoustic environment of schools, designers need to focus on controlling background noise, reverberation times and signal-to-noise ratios.

MATERIALS AND SURFACES Consider using a suspended acoustical ceiling (full) or acoustical cloud (partial ceiling) to provide sound absorption to reduce interior noise within a room. Other products such as carpet or neoprene chair leg tips can help reduce the production of noises.

INSTRUCTIONAL EQUIPMENT Locate instructional equipment (computers, printers, AV equipment, etc.) in areas of classrooms that will minimize their background noise.

MECHANICAL NOISES Locate mechanical sources of background noise (fans, plumbing, air conditioners, heating ducts, etc.) away from critical listening environments. Position HVAC system equipment over hallways or outside the building to minimize the background noise they create. Avoid trunk lines run in a straight line to minimize sound carried from adjacent spaces.

Reducing reverberation

Excessive reverberation can cause echoes that interfere with speech intelligibility. As a result, it is important to develop design strategies that minimize reverberations to improve speech intelligibility.

To help limit the impact of reverberation on the classroom environment, consider these measures:

- Increase the amount of soft, rough, or porous sound-absorbing surfaces (acoustical ceiling, carpeting, bookcases, etc.) and decrease the amount of smooth, hard sound-reflecting surfaces (exposed concrete walls, glass, etc.).
- Install acoustical tiling with a sound absorption coefficient of at least 0.65 to cover hard, sound reflective ceilings.
- In classrooms without a fixed lecture position and ceilings are less than 10 feet high, consider placing most or all of sound-absorbing materials on the ceiling. With ceilings more than 10 feet in height, consider placing some sound-absorbing materials on the wall.
- In classrooms with fixed lecture positions, consider ringing the upper wall and ceiling with sound-absorbing materials.
- Place sound-absorbing materials on the rear wall of classrooms to prevent sounds from echoing back to the front of the classroom.

Improving signal-to-noise ratio

Consider the use of hearing-assistive technologies such as personal frequency modulation (FM), sound-field FM amplification systems, induction loop, infrared voice transmitters, or hard-wired voice transmitters to offer children with hearing loss adequate SNRs.

At the same time, however, understand that classroom amplification systems should be considered in addition to, not as an alternative for, optimal classroom acoustical design.

Additional acoustical design considerations

In addition to the measures suggested for general classrooms, consider these design strategies to enhance the learning environment of spaces that have unique acoustical requirements:

CLASSROOMS FOR THE HEARING IMPAIRED Install high performance acoustic ceiling tiles (Noise Reduction Coefficient of 0.95) to reduce reverberation times. Reverberation times in classrooms for hearing-impaired students should not exceed 0.4 seconds.

MUSIC ROOMS Include more sound-absorbing surfaces in rooms primarily used for teaching and more sound-diffusing surfaces in rooms primarily used for performance.

LECTURE HALLS/AUDITORIUMS In small halls, use sound-reflecting materials above the lecturer to create sound reflections into the audience. Use sound-absorbing materials and/or tilt the back wall to minimize echoes and unwanted reflections. In large halls, consult an acoustic professional to provide sufficient reverberation control.

LIBRARIES Mask distracting noises with steady, non-distracting sounds such as an unobtrusive ventilation system. Install carpet to reduce sound production levels.

GYMNASIUMS Hang sound-absorbing baffles or banners from the ceiling to reduce reverberation times. Install acoustical panels or bleachers on at least one of two parallel walls.

HALLWAYS AND CAFETERIAS Install sound-absorbing materials in areas equal to 50-75% of the ceiling surface area. In high traffic areas, attempt to cover 75% of the ceiling area.

The need for collaboration

It is important for architects, designers, building contractors, school facility managers, equipment suppliers and acoustic professional to communicate and coordinate efforts in order to adequately control noise and improve acoustics in the learning environment. After construction is complete, all involved should also monitor the space for degradation of acoustical materials and respond to any complaints about the acoustical environment.

Meeting ANSI S12.60-2002

Two popular building performance standards assess a school's acoustic environment. The first is the "American National Standard Acoustical Performance Criteria, Design Requirements and Guidelines for Schools," commonly referred to as ANSI S12.60-2002. (reference website to download)

This document provides a minimum standard for the acoustic performance of general education classrooms and secondary spaces. Although ANSI S12.60-2002 is not mandated by all state codes, ordinances and regulations, it may be beneficial to adhere to the standard to create satisfactory acoustic environments.

Meeting LEED® for schools 2009

The second commonly used building performance standard is "Leadership in Energy and Environmental Design (LEED) for Schools."

To obtain a LEED point for acoustical performance for a new or substantially renovated school, unoccupied classroom background noise levels cannot exceed 45 dB(A). In addition, classrooms smaller than 20,000 cubic feet require the total area of sound-absorbing finishes with a minimum NRC rating of 0.70 equal to the room's ceiling area, while classrooms larger than 20,000 cubic feet require a reverberation time of less than 1.5 seconds.

An additional LEED point can be attained by limiting the unoccupied background noise to below 45 dB(A) and constructing all core learning environment walls with the minimum STC rating per room purpose specified in ANSI S12.60-2002.