Classroom Design for Good Hearing

BY EWART A. WETHERILL

Classrooms may be noisy...
simply because of the way
they are constructed and finished.
It is a shocking fault, for the need to hear well
is basic in education.

McQuade, *Schoolhouse,* 1958

In the summer of 2002, the American National Standards Institute published Standard 12.60, a totally new standard that provides acoustical performance criteria, design requirements and design guidelines for new classrooms and renovation of existing classrooms. The goal is to ensure a high degree of speech intelligibility in learning spaces. In order to achieve this, the noise level in an empty classroom should be kept to less than 35 decibels, and reverberation or echoes controlled.

While the impetus for the standard began initially as an effort to improve schools for children with impaired hearing or other learning disabilities, children with normal hearing will also benefit greatly from these standards.

The good news for architects and builders is that compliance with the acoustical standards need not be costly if they are incorporated early into the planning and design process, although remodeling existing facilities could be expensive depending on the actual situation. The requirements for good hearing were first presented formally to the American Institute of Architects in 1898 and have been successfully applied to many schools. However, in the absence of enforceable standards far too many schools have been built with little or no concern for good hearing. **Since acoustical problems are created by the design they can just as easily be avoided by the design.**

EXISTING CONDITIONS IN U.S. SCHOOLS

Elementary and secondary education, the nation's largest public enterprise, is conducted in more than 80,000 schools in about 15,000 districts. America's public schools serve more than 42 million students.

In February 1995, the U.S. Government Accounting Office (GAO) presented a report to the U.S. Senate on the results of a survey of school officials across the country on the physical condition of their facilities. The report comprised hard facts concluding that more than $100 billion would be needed to restore all of the schools to good condition. The most frequently mentioned of all the "unsatisfactory environmental conditions" was "acoustics for noise control."

One outstanding example of acoustical inadequacy can be found in the standards set by the Los Angeles Unified School District, one of the largest in the country. These allow the use of classroom ventilation/air conditioning units that are up to 20 decibels noisier than would be permitted by Swedish standards. The inevitable conclusion is that school children cannot hear much of what is said, while teachers must shout to be heard at all. A second example that should be familiar to many was the disastrous trend in the late 1960s to open-plan schools. These created a situation in which some school children could hear the teacher of an adjacent class more clearly than their own teacher.

Thus, a combination of outdated facilities and unfortunate design or construction decisions leave us with an inheritance that will be a burden for decades to come. This legacy of past policies will consume a very significant part of the limited funds that many communities seem currently willing to allot to school construction or renovation; so skillful planning and site selection will be essential to attain the new goals.

CHILDREN AT RISK

In December 1997, representatives of eleven national groups joined the Acoustical Society of America in a workshop on Eliminating Acoustical Barriers to Learning in Classrooms. From this workshop has developed a coalition that worked actively to further improved hearing conditions in schools. Leaders in the field of audiology and a wide range of disciplines related to design and construction of educational facilities presented the results of surveys and research on the prevalence of hearing disorders and substandard facilities, and their effects on hearing. The truly alarming statistics clearly show the disadvantage resulting from poor hearing conditions for both normal and hearing-impaired school children.

Studies of speech recognition confirm that an adult

listener hearing words in the context of a sentence can fill in words or syllables that are not heard clearly, depending on the size of the listener's vocabulary. Since children have smaller vocabularies, they are less able to fill in the words not heard clearly. Similarly, someone using English as a second language or someone who suffers from an attention deficit disorder are at a significant disadvantage in a noisy classroom. In addition, many children with usually normal hearing have temporary hearing losses from illness. *Otitis Media*, a bacterial infection of the middle ear that is the most frequently-occurring childhood medical complaint, has more than doubled in the last decade.

Compounding the learning disadvantages that confront children in noisy classrooms or with impaired hearing are the constant discouragement and frustration that can inhibit the motivation of even the most talented to learn and to excel.

The importance of clearly hearing the teacher seems self-evident, but this has not been a design criteria of many schools in the past.

Requirements For Good Hearing

Two basic criteria must be satisfied to meet the requirements for good hearing:

1. A quiet background (e.g. noise from intruding traffic, adjacent classes, ventilation systems etc.)
2. Control of reverberation and self-noise

Speech to Noise Ratio

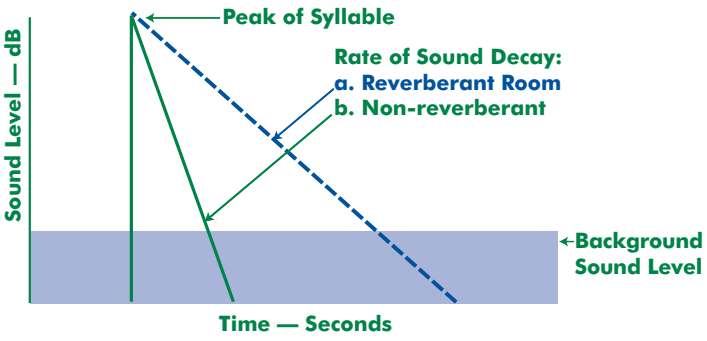
Speech in the classroom must be heard over the prevailing background noise level, be it intruding noise from traffic, adjacent classes, or a noisy ventilation system. A convenient and easily measured descriptor is the Speech to Noise ratio (S/N). There is general agreement that desired S/N ratios for speech recognition are:

Normal-hearing:
Adults: at least 6 decibels
Children: greater than for adults, at least 10 decibels

Hard-of-hearing listeners
Adults: at least 15 decibels,
Children: greater than for adults

By contrast, a survey of actual classroom conditions taken between 1965 and 1968 indicated a Speech to Noise ratio range from +5 decibels to -7 decibels. This information alone adds support to the growing concern both for children's understanding and for teachers' voice strain.

figure A



Rate of Sound Decay

Reverberation (commonly known as an echo) is defined as the persistence of sound in a room after the source has stopped. In a reverberant space, successive syllables blend into a continuous sound, through which it is necessary to distinguish the orderly progression of speech. The level at which this sound persists is determined by the size of the space, the speech level and the interior finish materials. Reverberation time (the time it takes for a sound to die off) is measured in seconds, with a low value—around 0.5 seconds or less—being optimum for a classroom seating about 30 children. Reverberation can be controlled by the use of readily-available sound-absorbing wall and ceiling materials that comply with building code requirements.

Effects Of Noise And Reverberation On Speech Recognition

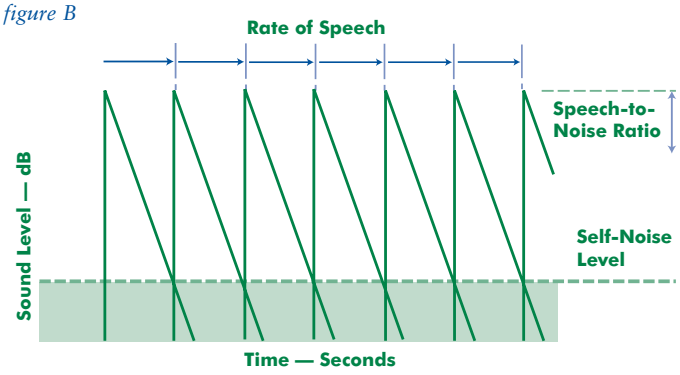
Mean speech-recognition scores (the percent of words correctly recognized) of adults with normal hearing for various S/N ratios clearly demonstrate the connection between good acoustics and effective hearing.

S/N ratio	Word Recognition
+12 decibels (low-background noise)	95.3%
+6 decibels	80.7%
0 decibels (high-background noise)	46.0%

Mean speech-recognition scores (in percent correct) of children for monosyllabic words with various reverberation times (RT) show a similar correlation.

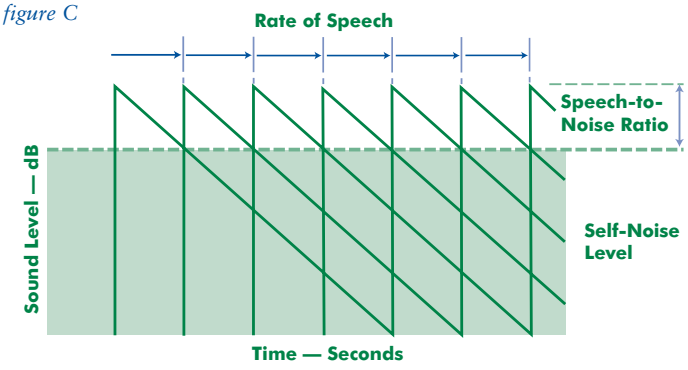
RT - Seconds	Normal Hearing	Hearing Impaired
0.0 (no echo)	94.5 %	87.5%
0.4	82.8%	69.0%
1.2 (persistent echo)	76.5%	61.8%

figure B



Speech in a Non-Reverberant Space

figure C



Speech in a Reverberant Space

In a reverberant room, teachers must compete with their own echo (self-noise) which raises the overall noise level in the room.

The combined effects of poor Speech to Noise and long reverberation time for children, which is the actual situation encountered daily in many of the nation's schools, are predictably a substantial handicap to entire classes. The following scores are for monosyllabic words.

Test Condition	Normal Hearing	Hearing Impaired
FOR REVERBERATION TIMES OF 0.0 SECONDS:		
+12 decibels	89.2%	70.0%
0 decibels	60.2%	39.0%
FOR REVERBERATION TIMES OF 1.2 SECONDS:		
+ 12 decibels	68.8%	41.2%
0 decibels	29.7%	11.2%

The following conclusions can be drawn from these test results and from corroborating evidence compiled from other test situations.

1. Understanding of children with normal hearing can be seriously affected by a combination of excessive background noise and reverberation.
2. Hearing impaired children are always at a disadvantage compared to those with normal hearing but the difference can be minimized by acoustical controls.
3. Comprehension levels for multisyllabic and unfamiliar words can be expected to be worse than indicated by monosyllabic testing.
4. Decrease in intelligibility with distance from the teacher can be minimized by acoustical treatment and shaping of the space.

Effect on Teachers

In addition to children's hearing concerns, the effect of trying to compete with an acoustically-difficult environment creates a problem of severe strain on the vocal chords for many teachers. While not as well-known or studied as the listener's ability to understand, voice strain is belatedly being recognized as a serious and potentially incapacitating problem for teachers. However, effective acoustical treatment of a classroom can create significant benefits here also.

Examples Of Effective Classroom Design

Designers and builders can improve hearing conditions in schools by incorporating the basic principles of acoustics into classroom design. For every new and remodeled school, the control of unwanted sounds and enhancement of wanted sounds, without the complications inherent in general amplification, should be placed high on the list of design goals. For new classrooms accommodating from 30 to 40 children these requirements should not add anything to the cost of either design or construction. However, correction of acoustical deficiencies in existing facilities could be costly, depending on the particular situation.

At least the following considerations must be addressed:

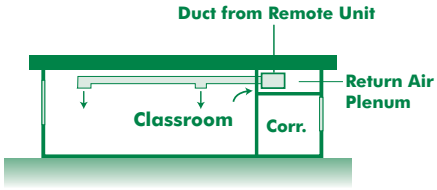
Control of unwanted sounds

- locate schools away from highways, rail tracks, and flight paths
- minimize noise intrusion from outdoors *(figure D)*
- minimize interference between classrooms
- design quiet ventilation system *(figures E and F)*

figure D

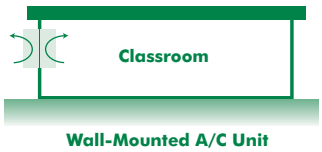
Control of Intruding Noise

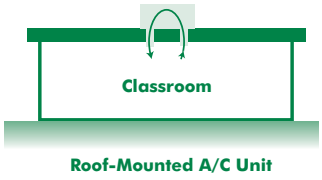
figure E



Preferred Layout for Noise Control

figure F





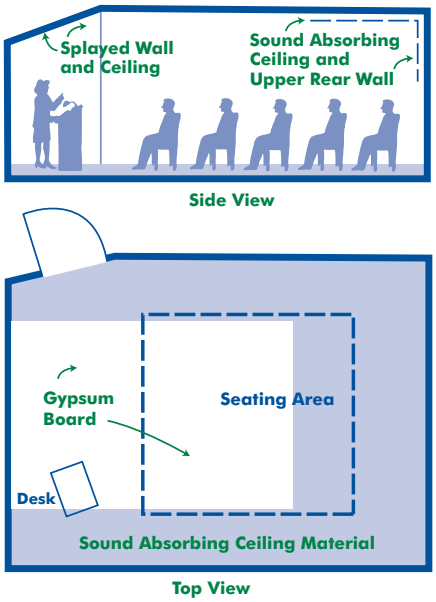
Built-in Noise Problems To Be Avoided

Enhancement of wanted sounds

- control excessive reverberation by sound absorption
- minimize echoes from distant surfaces (such as the back wall)
- use hard materials for useful sound reflections (such as on surfaces beside and above the teacher)

Figure G shows a suitable acoustical treatment for a "traditional" classroom configuration. For other desired class uses, redistribution of the required sound absorption may be appropriate. The booklet *Classroom Acoustics*, available at NPC's website, www.nonoise.org/quietnet/qc/, and the ANSI Standard S12.60 are of help when working with teachers and administrators.

figure G



Acoustical Treatment for a Classroom

Classroom Design for Good Hearing *is reprinted from* The Quiet Zone, *the newsletter of the Noise Pollution Clearinghouse. It appeared in the Fall 2002 issue.*

The Noise Pollution Clearinghouse is the largest national non-profit organization working to reduce noise pollution. It's website, www.nonoise.org is the world's largest online noise library, with 2,100 users each day and more than a gigabyte of data concerning noise pollution. For more information about noise and schools, call NPC toll free at 1-(888)-200-8332 and ask for a copy of the Fall 2003 newsletter and a list of further reading concerning schools and noise. Also, see Classroom Acoustics at www.nonoise.org/quietnet/qc/.

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